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VITAL CAPACITY OF THE LUNGS

VITAL CAPACITY
OF THE
LUNGS

A HANDBOOK FOR CLINICIANS AND OTHERS INTERESTED IN THE EXAMINATION OF THE HEART AND LUNGS BOTH IN HEALTH AND DISEASE

BY

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WITH INTRODUCTION

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Affectionately dedicated to
MY PARENTS
to
CLEMENT L. MCCRACKEN
and to the memory of his wife
JENNIE E. MCCRACKEN
Whose willing personal sacrifices have lent
generous support and encouragement to my scientific
and professional endeavors

PREFACE

The study of the vital capacity of the lungs alike in health and disease has received widespread attention during the past decade. In the development of a new diagnostic test or the revival of an old one there is usually a group of individuals who grow over-enthusiastic and make extravagant claims for it, while another group of individuals minimize and discredit its value at every opportunity. The vital capacity test, since its scientific introduction of more than three-quarters of a century ago, has been the subject of extravagant promotion as it has of severe criticism. However, it has stood well the test of time and today is regarded by scientific investigators, internists, pediatricians and general practitioners as a valuable aid in diagnosis, prognosis and the guidance of treatment of certain diseases particularly of the heart and lungs. An eminent surgeon has pointed out that even in operative work upon the chest many lives may be saved through a careful study of the vital capacity of each patient before operation; while another has stated that a careful estimation of the vital capacity may closely parallel the results of a general examination and a recent study has shown that it may be of great aid to the surgeon in the determination of operative risks.

So general are the applications of this method and so rapidly is it being adopted by physicians and scientific workers that a definite need has developed for a hand book on vital capacity. I have, therefore, in this small volume attempted to bring together the chief facts which we now

possess concerning the percentage of any given person's normal vital capacity, making these available without the use of any mathematical calculations or an understanding of the mathematical formulae from which the tables were derived. These tables are sufficiently accurate for the scientific investigator and so easy of application that the busy practitioner of medicine may use them with a minimum expenditure of time. Several tables, based on various formulae, are presented so that the scientist who wishes to make comparisons of the various standards may do so. The tables in most general use by physicians at the present time are indicated for practitioners who in their clinical work do not wish to make a special study of vital capacity but only to use the most approved method as an aid to diagnosis, prognosis and the guidance of treatment.

The significance of the vital capacity test in various diseases is discussed and a bibliography is included, in order that those who desire to delve more deeply into this subject may be able quickly to obtain reference to the leading works in its literature.

This volume is presented with the sincere hope that it will stimulate research, resulting in many new contributions to our knowledge of the subject, and will prove of distinct aid to practitioners of medicine in the diagnosis, prognosis and treatment of their patients.

I desire to express my indebtedness to Dr. L. G. Rowntree, of the Mayo Clinic who stimulated my interest in the vital capacity problem in 1919, and to Dr. S. Marx White of the University of Minnesota under whose direction most of my research on this subject has been conducted. For financial aid I am indebted to the Hennepin County Tuber-

culosis Association and to the Graduate School of the University of Minnesota for special research grants. I am also greatly indebted to those who have offered valuable criticisms and suggestions: Dr. E. P. Lyon, Dean of the Medical School of the University of Minnesota; Dr. H. S. Diehl, Chief of the Department of Preventive Medicine and Public Health; Dr. R. E. Scammon, Professor of Anatomy; Dr. R. O. Beard, Associate Professor of Physiology; Dr. H. L. Ulrick, Associate Professor of Medicine; Dr. C. A. Stewart, Assistant Professor of Pediatrics; Dr. M. H. Nathanson, Department of Medicine;—all of the University of Minnesota; Dr. E. S. Mariette, Superintendent, Glen Lake Sanatorium; Dr. F. L. Jennings, Associate Medical Director, Glen Lake Sanatorium; Dr. Willis S. Lemon, Associate Professor of Medicine, Mayo Foundation, Rochester, Minnesota; Dr. Herman J. Moersch, Mayo Foundation, Rochester, Minnesota; Dr. David A. Stewart, Superintendent of Manitoba Sanatorium, Ninnette, Canada; Dr. R. G. Pearce, Division of Diagnosis and Research, Goodrich Company, Akron, Ohio; Dr. R. E. Boynton, Director of Child Hygiene, Minnesota State Board of Health; and Dr. W. P. Shepard, Commissioner of Health, Berkeley, California.

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INTRODUCTION

Recent advances in the study of vital capacity have revived general interest in this important field and Dr. Myers has undertaken to place the subject in compact form for reference and daily use by clinicians and others interested in vital capacity alike in health and disease.

Numerous observers, beginning with von Basch, have pointed out for example that in beginning cardiac decompensation reduction in vital capacity may occur before the râles at the lung bases, so long sought for as an early sign, appear.

At the University of Minnesota Dr. Myers, during the last six years, has occupied himself with the study of vital capacity with particular reference to its significance in health, as an index of physical fitness, and he emphasizes its importance in conjunction with other standard means of study in the diagnosis, prognosis, and study of the progress of pathological conditions of the chest. He emphasizes also the fact that patients suffering from disease outside the heart and lungs which cause extreme weakness have a reduction in physical fitness greater than the vital capacity test indicates.

The brevity and clearness of presentation will make an appeal, I am sure, to the clinician and the practitioner interested in this field. The addition of a bibliography of over two hundred references brings the literature together in so complete a manner as to interest the technical student as well. The wealth of tables and illustrations makes this little monograph an exceedingly handy and useful handbook.

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Minneapolis, Minnesota
March 31, 1924

CHAPTER I

The History of the Study of Vital Capacity

On first thought it seems strange that a phase of the functions of the human lungs could escape scientific studies and record through so many centuries of man's existence upon the earth. On second thought, however, considering the extreme persecutions to which men in earlier times were liable and to which they were frequently subjected, even to the loss of life itself, for the attempting to advance human knowledge, it is the more remarkable that the flame of investigation could have burned so brightly in the life of any individual as to permit others to become conscious of its glow. Nevertheless this flame once lighted was kept burning, although dimly at times, and has so increased in intensity in the last few centuries as greatly to enlighten the world.

Hippocrates, Plato and others of their time believed that the blood was tempered in the lungs and that the lungs were placed near the heart "to keep it cool and in exact obedience." Galen believed also that the lungs expand with the chest and that the air is drawn into the lungs in this manner. His views were not accepted and it was not until the time of Boyle that they received much attention. Boyle held that the lungs become filled with air because the chest dilates and that the movements of the chest are necessary for the filling of the lungs. He taught that the diaphragm and intercostal muscles take a considerable part in respiration. Lower, at about the same time, described quite correctly the act of respiration and did some experi-

mental work on dogs in which he actually studied respiration after section of the phrenic nerve. Until the eighteenth century the belief prevailed that air ordinarily exists between the two layers of the pleura.

Hutchinson pointed out that the first great epoch in the history of respiration may be dated from the year 1628 when Harvey published his first work on the circulation of the blood.

In 1667 Hook demonstrated that it was possible to keep a dog alive by artificial respiration performed with bellows. A little later, Fabricius explained in some detail and quite correctly the action of the diaphragm. The rôle which the intercostal muscles play in respiration was discussed considerably at that time and has been a subject of much discussion since. It is interesting to note that much of our information on this subject has been contributed by a present day investigator, C. F. Hoover.

During the latter half of the eighteenth century, much productive study was made of the composition of air, and especially of respired air. Some of the names associated with this work are Lavoisier, Priestly, Ruthford and Scheele. Hutchinson considered this period the second great epoch in the history of the study of respiration.

Apparently the first attempt to investigate the volume of air taken into the lungs at a single breath was made by Borelli in 1679. Jurin later carried on the work and concluded that the greatest volume of air that could be forced from the lungs after the deepest possible breath (the vital capacity), was about 220 cubic inches. In 1708 Keill made quite careful measurements of the air expired from the lungs. Hales, again, calculated the vital capacity at approximately 220 cubic inches. From a study of the vital

capacity of 12 men Thompson found a variation of from 100 to 250 cubic inches with a mean volume of 186½ cubic inches. Davy found his own vital capacity to be 213 cubic inches, while Goodwin and Menzies state that the vital capacity of adult men is in the neighborhood of 200 cubic inches. Kite found that an individual of moderate size might have a vital capacity of as much as 300 cubic inches, while Bostock and Dunglison believed 210 cubic inches to be about the usual vital capacity for adults. Thackrah studied the vital capacity of nineteen soldiers and found the mean to be 217 cubic inches.

Thus we see that a wide diversity of opinion existed as to the vital capacity of the lungs. This is easy to understand when it is considered that no standard instrument had been devised for measuring accurately the vital capacity and that the observations of most workers were limited to a very small number of persons. In some instances only a single case was reported, and the size and condition of the body were apparently given little consideration.

Seemingly it was left to Hutchinson to place on record the first painstaking and scientific investigation of the vital capacity of man. His paper, published in 1846, contained illustrations and descriptions of the spirometer he had invented. In addition, his study contained the results of his observations of approximately 3000 people, some of whom were in good health while others were suffering from diseases of the lungs. Hutchinson's work also paved the way to the accurate measurement of the tidal air, the supplemental air and the complemental air, and to the calculation of the residual air and, later, to the collection of respired air for basal metabolism determinations, etc. This may be considered the beginning of the third great epoch

in the history of the study of respiration. That Hutchinson was a true scientist cannot be doubted after one reads the following concluding paragraphs of his paper.

"The matter of this communication is founded upon a vast number of facts—immutable truths, which are infinitely beyond my comprehension. The deductions, however, which I have ventured to draw therefrom, I wish to advance with modesty; because time, with its mutations, may so unfold science as to crush these deductions, and demonstrate them as unsound."

"Nevertheless the facts themselves can never alter, nor deviate in their bearing upon respiration—one of the most important functions in the animal economy."

Hutchinson stated that the vital capacity of man may be considered as a constant quantity, but that this quantity is directly disturbed or modified by four circumstances, namely, height, weight, age and disease. He decided that of all measurements height bears the closest relationship to vital capacity. His observations led him to believe that there exists no direct relation between the circumference of the chest and the vital capacity.

Only two years after Hutchinson published his paper, Gustav Simon (1848) made a study of this subject and took issue with Hutchinson as to the relationship existing between chest circumference and vital capacity. He believed that for every increase of 1 inch in chest circumference 191 cc. of air is added to the vital capacity. He placed a great deal of emphasis upon the size and mobility of the chest in health, but pointed out that increased size in such conditions as emphysema is not accompanied by increased vital capacity.

In 1853, Fabius studied the vital capacity of both men

and women. The majority of his subjects were normal individuals ranging in age from ten to sixty-four; but, he made observations also on several persons suffering from such diseases as phthisis. In addition to the measurements employed by his contemporaries, his studies led him to believe that a close correlation exists between the vital capacity of the lungs and the length of the trunk from the coccyx to the occipital protuberance. He believed that stem height is a more necessary measurement than standing height. Recent analyses of his data have shown, however, that he was not justified in his conclusions.

Voorhelm Schneevogl (1854) investigated the vital capacity of 300 people. He first studied the capacity of normal men, then of normal women and, finally, of persons suffering from disease. For the most part he employed the height standard of Hutchinson. He found that women have vital capacities of from 600 to 700 cc. less than men. His observations showed further that women, 150 centimeters in height, possess a vital capacity of 2000 cc. and that for each additional centimeter in height the vital capacity is increased 30 cc.

Wintrich in 1854 made a study of the vital capacity of 3500 individuals. Among them were 500 non-pregnant and 52 pregnant women. He found that for each centimeter in height, men exhale 22 to 24 cc. of air, while women exhale from 16 to 17.5 cc. He assigned to age a dominating influence upon vital capacity. The largest vital capacities he observed were in persons between the ages of twenty and forty years. Between the ages of six and eight years he found that for each centimeter of height, for both boys and girls, 6.5 to 9 cc. of air are exhaled; that from ten to twelve years the amount of air exhaled was 11 to 13 cc.;

while from twelve to fourteen years the volume of air was increased from 13 to 15 cc. per centimeter of standing height. He found that the sex difference became more noticeable between the ages of fifteen and twenty years.

Between the ages of forty and fifty years Wintrich found a slight decrease in the vital capacity; while between the ages of fifty and sixty years he observed great variation in vital capacities. In well developed people, even at sixty-four years and over, he found that the vital capacity did not differ greatly from that of people between the ages of forty-five to fifty-five years. In people after seventy-six years old Wintrich observed a decline in vital capacity to that of the childhood ages. Although old women were found to decrease less rapidly than old men the sex differences were found to continue into the greatest ages.

Only one year later, Arnold (1855) made a thoroughgoing study of the vital capacity of 216 adult individuals. He confirmed Hutchinson's work but believed that chest circumference and expansion were quite closely correlated with the vital capacity of the lungs.

Following the work of Arnold, Müller (1868), Waldenburg (1880) and others made quite extensive studies in vital capacity. In 1884 George Cornet, who later became an international figure in the field of tuberculosis, published his inaugural dissertation on the subject of vital capacity. He tabulated his findings in 47 men and 41 women. In these groups he made a careful study of the relation of vital capacity to age, standing height, weight, trunk height, chest circumference, occupation and disease.

Following the work of Cornet, Garmault (1905), Rubow (1908), Siebeck (1910), Staehelin and Schutze (1912), Plesch (1913) and others made careful studies of various phases of the subject.

During the world war many phases of scientific investigation were stimulated tremendously. The very struggle for existence brought out from all nations the best that could be found and consequently many scientific facts were added to the store of knowledge of the human family. It was during this time that the vital lung capacity test found one of its most useful periods. For various branches of the service, men were needed in great numbers and time did not always permit a careful and complete physical examination; any test, therefore, which would quickly eliminate those afflicted with serious conditions of the heart and lungs was of great value. Georges Dreyer, working with the British forces, pointed out that the vital capacity test was being used as a routine in the examinations of candidates for the British Flying Service and that it served as a decisive factor in election to or rejection from that service. Dreyer states that "A definite minimum standard of vital capacity was fixed more or less arbitrarily for the admission of cadets to the Royal Air Force and standards were also decided upon for the grading of flying officers for different types of service. In laying down rules in this connection the question of the size of the man was entirely disregarded, as though of no consequence, and the standards were arrived at simply as the result of examining a number of successful pilots and determining the average vital capacity." It was this experience which stimulated Dreyer to investigate further the subject of vital capacity, and in turn resulted in his notable publications on the subject. Schneider, working with the American forces at the same time, made considerable use of the vital lung capacity test.

Already the vital capacity fire was burning in America,

for Peabody and Wentworth, West and others of Harvard were investigating this subject and publishing the results of their splendid work. In the fall of 1920 Professor Dreyer spent a considerable time lecturing on this subject in the various medical centers of America. So stimulating and convincing were his lectures that numerous investigations in various parts of this country followed in his wake. These investigations have been concerned, not only with the vital capacity of normal individuals, but also with the effects of certain diseases upon vital capacity, with the result that many findings of the earlier writers have been confirmed and a good many new facts have been and will continue to be added to our store.

SUMMARY

The first great epoch in the history of the study of respiration may be dated from the year 1628 when Harvey published his first work on the circulation of the blood. The second great epoch in the history of the study of respiration began during the latter half of the eighteenth century when much productive study was made of the composition of air, especially respired air. Apparently the first attempt to investigate the vital capacity was made about 1679. Between this date and 1846 several scientists studied vital capacity. Hutchinson placed on record the results of the first painstaking and scientific investigation of the vital capacity of man in 1846. This work led to the accurate measurement of the tidal air, the supplemental air, and to the calculation of the residual and later to basal metabolism determination. Hutchinson's work may be considered the beginning of the third great epoch in the history of the study of respiration. Since Hutchinson's time many

investigators have studied vital capacity in large numbers of men, women and children both in health and disease. Much has been added to our knowledge of vital capacity, much remains to be done.

CHAPTER II

Factors Other Than Disease Which Influence the Normal Vital Capacity of the Lungs

Physical training. In using the tables in Chapter VI one finds some few persons who present vital lung capacities of as much as or more than, 125 per cent of the normal. Usually, these are people who have done hard labor, such as farm work, or who have been active in athletics, or have trained the voice for singing, or have played a wind instrument throughout a long period of time, or have indulged in some other activities which have led to an over-development of the lung capacity. In a few cases, however, no such history can be obtained; and there are often, among them, thin individuals with long chests and low placed diaphragms; in a word, those who belong to the hyposthenic or asthenic type described by Mills. Such individuals with over-developed lung capacities represent a more important group than one is apt to believe at first thought. Members of the group, after developing disease of the heart or lungs which decrease their vital capacities, may still have capacities of more than 100 per cent of the theoretical normal. Therefore, the mere fact that a given individual presents a vital capacity of 100 per cent or more of the theoretical normal does not prove that that individual is free from heart or lung disease which may indeed have definitely decreased the vital capacity.

Occupation. Ever since vital capacity has been studied it has been said to be materially influenced by occupation.

Hutchinson grouped his cases according to their occupation, as did numerous succeeding investigators. Dreyer believes occupation to be so important that he groups all people into three classes, which he designates as A, B, and C. In class A he places men in army or navy life; any one who has had long military or naval training regardless of his previous occupation; policemen, athletes and active sportsmen; university students (playing games); firemen, blacksmiths and boilermakers. In class B fall professional people (doctors, lawyers, etc.); business men, railway men, high-grade mechanics and clerks of the upper class. In class C he places tailors, shopmen, shoemakers, printers, potters, clerks of a lower class and painters. Dreyer believes that individuals who spend considerable time in the open air playing games, etc., may bring themselves into class A regardless of their occupations.

The tables (see Chapter VI) made from Dreyer's formulae are from his class A calculations. If one desires to use Dreyer's classification approximately 8.7 per cent must be deducted from the figures printed in the tables for persons falling in class B and approximately 14.6 per cent for those in class C.

Foster and Hsieh found that "Occupation seems to influence the vital capacity to some extent, although not in proportion to the degree of physical activity." It must be borne in mind that while occupation plays a considerable rôle in the vital capacity of a given case, there is much individual variation in vital capacity and that not all persons in a given occupation have uniformly low or high vital capacities.

Sex. Fabius investigated the vital lung capacity of the two sexes. A little later Schneevogl and then Wintrich

made extensive investigations pointing out that a definite difference exists between the vital capacities of men and women. Wintrich found that the sex variation is very

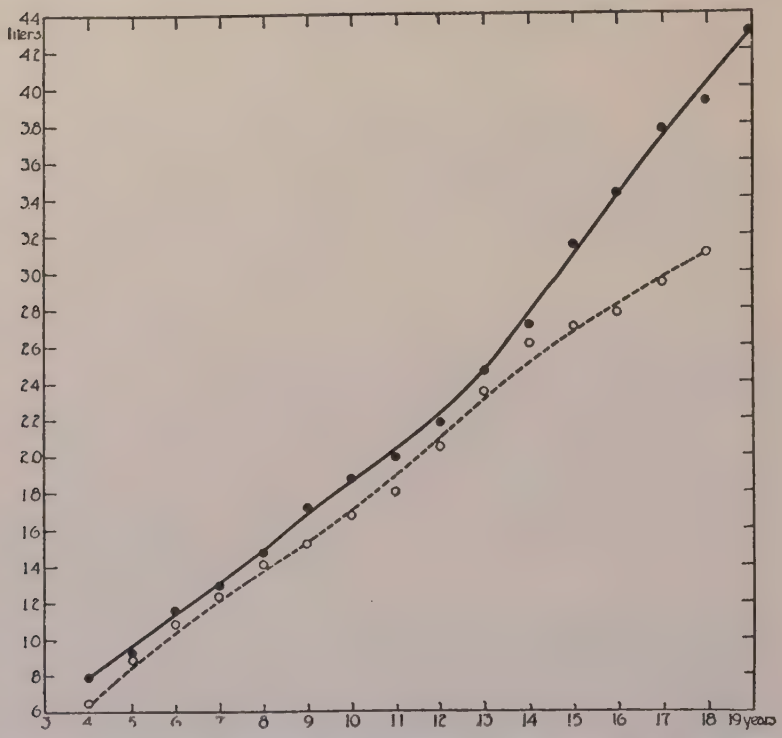

FIG. 1. SMOOTHED CURVES REPRESENTING THE AVERAGE ABSOLUTE INCREASE IN THE VITAL CAPACITY OF THE LUNGS

Determined by graphic interpolation, for boys between four and nineteen years of age inclusive, and for girls between four and eighteen years of age inclusive. The actual averages at each age for the boys are represented by dots and by circles for the girls. Vital capacity in liters is represented on the ordinate, and age in years on the abscissa. The solid line represents the boys; the broken line the girls in this figure. (After Stewart.)

slight during the early years, but becomes more noticeable after the fifteenth year of life. Stewart has shown graphi-

cally (fig. 1) that from the age of four years the vital capacity of boys is constantly slightly greater than that of girls until about the age of fourteen years, when the sex difference becomes more marked.

Wilson and Edwards found that the vital capacity of boys is 6 per cent greater than that of girls.

Schneevogl studied 40 women and found that their vital capacities averaged from 600 to 700 cc. less than men.

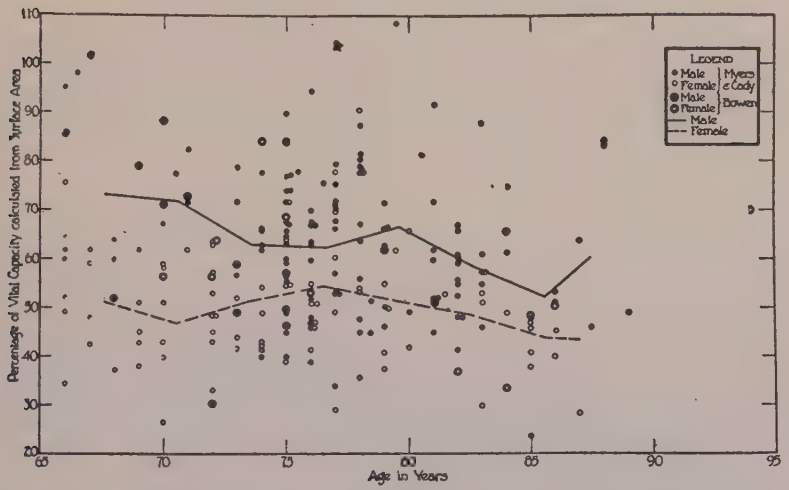

FIG. 2. EFFECTS OF SENILITY UPON THE VITAL CAPACITY OF MEN AND WOMEN
After Myers and Cady

In senile individuals Wintrich found that in general the sex difference continues up to the greatest ages. This finding was recently confirmed by Myers and Cady (fig. 2.).

The differences due to sex between young adult life and senility are such as to require separate normal standard tables for the two sexes (see Chapter VI).

Age. Hutchinson found that age has a very definite influence on the vital capacity of the lungs. He believed

that the maximum vital capacity of an individual is reached about the thirtieth year of life. Stewart's recent studies led him to believe that the maximum vital capacity of the lungs is reached in boys about the twentieth year and in girls slightly earlier than that time.

Wintrich pointed out that the ratio between the standing height and the vital capacity differs with the various ages of childhood and differs markedly from that in adult life. Recently, Stewart, Emerson and Green and Wilson and Edwards have made extensive studies on the vital lung capacities of children and have shown that standards used for adults are not applicable to children. Therefore, tables are presented (see Chapter VI) from which one may ascertain the normal vital lung capacity of a given child. Edwards and Wilson have called attention to the fact that the surface area standard is no more accurate than the standing height standard. They found, however, that the correlation between surface area and vital capacity in children very closely corresponded to that which West, Lemon and Moersch, and Myers found for women. Therefore, table 6, Chapter VI, may be used for either.

Peabody and Wentworth, in discussing vital capacity, stated that "weakness and old age may cause a slight decrease."

West says, "In addition, it is very desirable that more observations be made on elderly individuals, for age apparently reduces the vital capacity to an appreciable extent."

Pratt found that vital capacity is definitely reduced at advanced ages.

McKean, from personal observations in a considerable number of persons over forty years, states that "there seems to be a decrease normally to 75 or 80 per cent of the normal

standard for younger adults, as the tissue elasticity grows less."

Levison reported a small series of cases, beyond the age of sixty years, in which he found the vital capacity considerably decreased in most instances.

Bowen and Platt recently reported the results of their studies on the relation of age and obesity to vital capacity (fig. 3). Twenty-five of their cases were between the ages

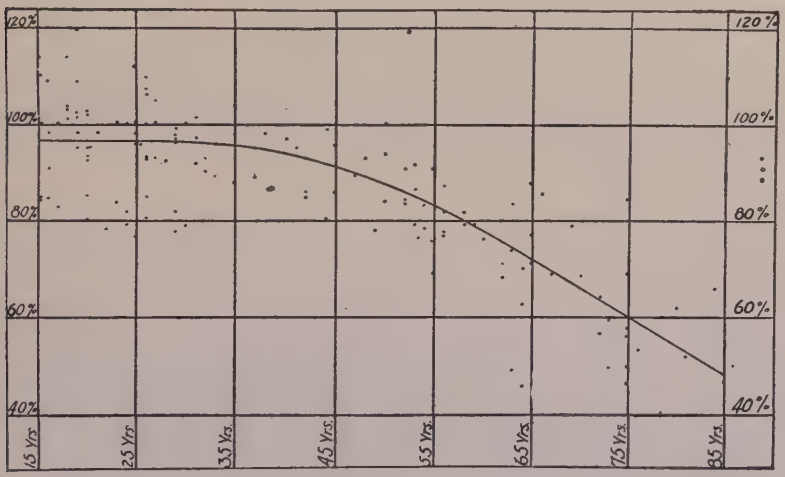

FIG. 3. EFFECTS OF AGE UPON THE VITAL CAPACITY
After Bowen and Platt

of fifty and sixty years, while 39 cases were fifty years or more. Their remaining 120 cases were between the ages of fifteen and fifty years. In this work Bowen and Platt employed the height and the surface area standards. They found that up to the age of fifty years the average vital capacity was 95.8 per cent of the normal. Then it gradually reached 50 per cent at the age of eighty-five years, the greatest fall in any decade being between the ages of fifty and sixty years.

Lemon and Moersch found that in a group of 165 men and 165 women, age did not influence the vital capacity to any marked degree before the ages of fifty or sixty years. They state that, "The degenerative changes which appear in men with advancing years and the changes in height and weight provide many reasons for such a decrease and are factors of such changing character and often so difficult to determine that they are equally difficult to evaluate in making estimations."

Myers and Cady observed that in those individuals who continue to lead active lives, the vital capacity does not decrease as much as in those who retire from work at the age of fifty to sixty years. They believe that those who do not retire until unfortunate physical conditions compel them to do so have a higher percentage of physical fitness and lead much happier lives than their retired friends.

Obesity. Hutchinson taught that an excess weight of 7 per cent or more interferes with the vital capacity of the lungs. The statement has been made frequently that overweight and obesity cause a decrease of vital capacity. More recent investigations, however, lead one to believe that only extreme obesity is capable of actually reducing the vital capacity, and then because of the deposit of fat in the abdomen and thorax which may limit somewhat the diaphragmatic excursion and thus decrease the capacity of the thorax. In this connection Bowen and Platt took 2 obese and 2 "overweight" persons and by dietary measures reduced the weight of each by more than 20 pounds in periods varying from two to ten months. In 2 of these cases the vital capacity increased, while in the others it remained unchanged. What happens in most cases is that when a normal individual becomes obese the added weight

is due to deposits of fat and not to the growth of the various organs. The lungs, therefore, do not grow; consequently, the vital lung capacity does not maintain its usual correlation with the weight and surface area of the body. In fact, Bowen and Platt have stated that in dealing with obese individuals one may use the height standard, or, if the sur-

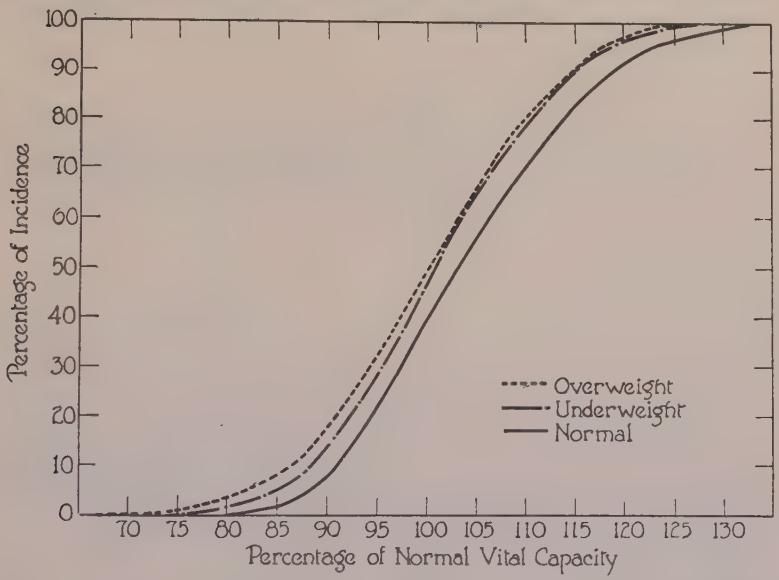

FIG. 4. CURVES SHOWING THE COMPARISON BETWEEN VITAL CAPACITIES OF NORMAL STUDENTS AND THOSE 10 PER CENT OR MORE UNDERWEIGHT OR OVERWEIGHT

After Myers and Shepard

face area standard is used, 20 per cent should be added to the observed vital capacity. Shepard and Myers have shown that the vital capacity is decreased in a group of college students 10 per cent or more underweight or overweight (fig. 4).

Posture. The posture of an individual affects in some degree the vital capacity of the lungs, as Rubow and others

have shown. Christie and Beams found that in a reclining position the vital capacity averaged 5.5 per cent lower than when the subjects were in the sitting posture. Rabinowitch recently investigated this subject in connection with some other work on vital capacity and found that if the vital capacity observed in the recumbent position is multiplied by the constant 1.075, the product may be accepted as the vital capacity which the same individual would present in

TABLE 1

Shows differences in vital capacity between normal Americans and normal Chinese

After Foster and Hsieh

	VITAL CAPACITY BODY SURFACE PER SQUARE METER	VITAL CAPACITY HEIGHT PER CENTIMETER
	liters	*cc.*
Americans:		
Men	2.5	25.0
Women	2.0	20.0
Children	1.93	15.5
"Athletes"	2.8	29.0
Chinese:		
Men	2.0	19.0
Women	1.5	14.0

the standing position. This is an important subject, inasmuch as one is frequently compelled to examine acutely ill patients in the recumbent position and should know, therefore, approximately how much of the reduction in vital capacity is due to posture.

Race and nationality. Dreyer pointed out that various races of people would probably be found to show differences in normal vital capacities. Wilson and Edwards examined a group of 38 average normal colored children ranging from eight to fourteen years. They found the vital capacity strikingly below that of any other group studied and

stated that "these findings suggest a possible racial factor." Foster and Hsieh made observations on 500 Chinese in several occupations, including a number of young women. They found that "the Chinese show much lower vital capacity ratios than Westerners." Table 1 shows a comparison between the standards obtained in Americans and in Chinese. The work which Dr. Conception has under progress at Manilla promises to throw much light on this subject.

In small groups of Chinese and Filipinos, I have found the vital capacities lower than among the white race.

SUMMARY

Several factors tend to effect the vital lung capacity of persons in good health. Excessive physical training and certain occupations may result in over-development of the vital capacity, while other occupations may retard its development. About the age of forty-five years there usually appears a reduction in vital capacity which becomes more marked as age advances. In obese persons the vital capacity does not maintain its usual correlation with the weight and surface area of the body. In the recumbent position it is usually about 5 per cent lower than in the standing position. Race and nationality definitely affect vital capacity. In the female it is lower than in the male, so much so in fact as to make separate normal standards necessary for the two sexes.

CHAPTER III

The Influence of Disease Upon the Vital Capacity of the Lungs

The spirometer was invented for the purpose of aiding in the detection of disease of the lungs. Hutchinson did his work on normal individuals because no normal standards were in existence. No sooner had he completed his normal standards than he began to use the spirometer as an aid in the diagnosis of tuberculosis. As those who followed him have been, Hutchinson was helped greatly by the vital capacity test. It is true that in those days many of the aids to diagnosis that we now have, such as tuberculin, x-ray and serologic tests, did not exist and the vital capacity test may have seemed more significant than it does at the present time. Nevertheless, numerous recent researches have proved beyond all doubt that the test is sufficiently important in diagnosis, prognosis, and in following the course of treatment in certain diseases that it well deserves a place in every routine examination.

Dreyer says, "If a person is found to have as much as 10 per cent less vital capacity than is normal for his class, it is *probable* that he is suffering from some health-depressing condition and if he is as much as 15 per cent below the normal limit, it is *practically certain* that he is abnormal in this respect."

After a careful study of a group of children, Wilson and Edwards state that "A reduction of vital capacity measurement of 15 per cent, or more, from the average normal standard should single the child out for further physical and roentgenographic examination."

It has been proved that disease of certain organs besides the lungs, and particularly the heart, is capable of reducing an individual's vital lung capacity. Abnormal conditions within the chest which decrease the vital capacity may be classified as (1) those of no present clinical significance, and (2) those of present clinical bearing. Conditions belonging to the first class are: Old pleural adhesions, deformities of the thorax, ossification of the costal cartilages, and to these may be added lack of coöperation and will-power on the part of the patient, malingering and unknown causes.

Old pleural adhesions, following such conditions as pneumonia and empyema, may reduce the vital lung capacity somewhat. Although the adhesions are of no clinical significance, they tend to bind the lung down. It should be understood clearly, however, that not all cases showing pleural adhesions present a vital capacity below the normal. In a group of 54 cases with thickened pleura, revealed by the x-ray, the average vital capacity was found to be 94.1 per cent while 26 cases of healed empyema presented an average vital capacity of 91 per cent of the normal.

Old deformities of the thorax and ossification of the costal cartilages and costovertebral joints are capable of reducing somewhat the vital capacity even though the intrathoracic organs are free from disease. We know that the chest capacity is increased by the elevation of the ribs and sternum and the descent of the diaphragm. It is obvious, therefore, that any condition which prevents the usual movements of the bony thoracic framework will decrease the vital capacity. Lemon and Moersch cite the case of a man with ossification and fixation of the costovertebral joints with complete immobilization of the thorax. His vital capacity was 32.1 per cent below normal, and yet he was able to par-

ticipate in certain athletic sports without the least discomfort or dyspnea. Under this same heading, one may mention disturbed function of the diaphragm and intercostal muscles which can cause definite decrease in the vital capacity. Other factors effecting a change in position of the diaphragm such as abdominal tumors, may be capable of decreasing the vital lung capacity. Not enough examinations have been reported to determine definitely whether or not it is influenced by pregnancy.

The work of Wintrich, Zhurakovski and Root and Root have thrown considerable light upon vital capacity in pregnancy. Dr. J. Warren Bell's studies (in progress) promise to add much to our knowledge of this subject. From more than one hundred readings on approximately 70 cases he believes that:

"Results based upon weight standards are illogical during pregnancy when weight changes are uneven, and in early stages when nutrition suffers and there is a weight loss.

"More satisfactory results are obtained in those cases where two or more readings make possible a comparison of the condition of heart and lung at various times.

"One instance of four readings during the last trimester shows a progressive reduction of vital capacity accompanying an increase in edema, dyspnea, blood pressure, and nervous instability.

"In pregnancy as elsewhere excessive reduction in vital capacity is usually accompanied by heart disease demonstrable clinically.

"Mechanical factors seem to play a surprisingly small part in vital capacity during pregnancy, as seen in a case of twins with an abdomen which was not small to say the least."

Lack of coöperation and will-power. There are patients who absolutely refuse or cannot be taught to coöperate and others who do not have the will-power to take the deepest possible breath and the greatest possible expiration. Among these are persons of hysterical type. Then, as Galet and others have pointed out, there is a group of persons who apparently do not know how to breathe deeply. Such persons present low vital capacities with no detectable pathologic condition in the chest.

Malingering. In these days when compensation is obtainable for disabilities incurred while in the employ of certain organizations one meets a few persons seeking compensation with no just cause. Such persons, and they are few, refuse to give their true vital capacities although they try to appear to be putting forth great effort. One must be on one's guard or such malingerers will present very misleading readings. Several very striking cases have come to my attention in the last few years, none of which is more interesting than the following: This man on several attempts registered a vital capacity of 3000 cc., which he stated was absolutely his best. He was sure that he had "consumption" and that a certain organization was responsible for his infection with this disease. I told him that a person with a "little" tuberculosis would have a much higher vital capacity and consequently I did not believe he had that disease. With a look of surprise he said: "Is that so? Well, let me try it just once more." This time the instrument registered 4000 cc., which was within normal limits. Further examination revealed no evidence of pulmonary tuberculosis.

Unknown causes. Occasionally one encounters a vital capacity 20 or 25 per cent below the normal when a careful

search reveals no apparent cause for the reduction. Hewlett and Jackson of Stanford University, found that slightly more than 1 per cent of 400 students examined by them belonged to this class. Further investigations may reveal definite causes for such cases. For the present, they are so uncommon as to interfere very slightly with the reliability or usefulness of the test.

Some of the factors of present clinical significance which decrease vital lung capacity are: Cardiac disease, hyperthyroidism, asthma, emphysema, bronchitis, pleurisy, pneumothorax, pulmonary abscess, bronchiectasis, new growths, pneumonia and pulmonary tuberculosis.

Cardiac disease. Von Basch, Rubow, Siebeck, Peabody and Wentworth, Lavine and Wilson, Adams and Sturgis, Ulrich and Nathanson, Burton-Opitz, Pratt, Lattimore, Ziskin and Levison have made valuable contributions to our knowledge of vital capacity in heart disease. The work of these investigators has proved that vital capacity readings aid in diagnosis, prognosis, and in guiding the treatment. It has been pointed out (Ulrich and Nathanson) that in patients complaining of cardiac symptoms, the vital capacity aids in determining the presence or absence of cardiac involvement. Some striking cases are cited of patients who appeared to have marked symptoms of cardiac disease, yet their vital capacity was normal and further examination proved the absence of cardiac disease. Adams and Sturgis found that in one hundred cases of "effort-syndrome," complaining of dyspnea, the vital capacity was within normal limits. Levison says, "The vital capacity of cardiac patients runs roughly parallel to their dyspnea and this fact may be utilized in differentiating true from false dyspnea."

On the other hand, when cardiac disease does exist the

vital capacity test gives reasonably accurate information concerning the functional capacity of the heart. Peabody and Wentworth and Ulrich and Nathanson have shown that the reduction in vital capacity closely follows the clinical condition of the patient, varying directly with the degree of cardiac impairment. It has been stated that, as a rule,

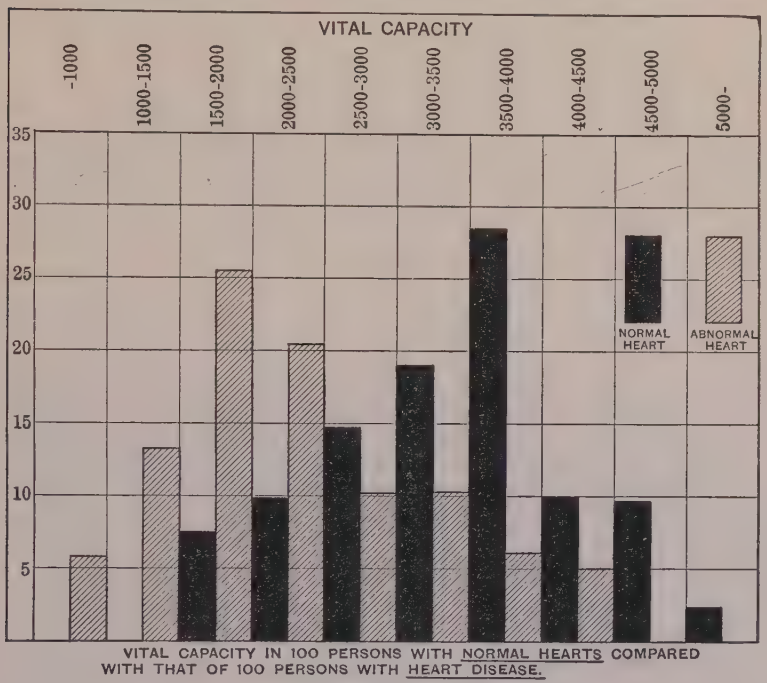

FIG. 5
After Pratt

the lower the vital capacity, the poorer the prognosis. This does not hold true in every case, however, since certain patients with acute decompensation may show a very low vital capacity which increases materially as compensation is established. Other patients, on the verge of developing decompensation or other conditions which usually warrant

a grave prognosis, may have a good vital capacity. This presents the actual functional capacity of the heart at the time the reading is taken, but yields no information as to the progressiveness of the lesion. Subsequent readings,

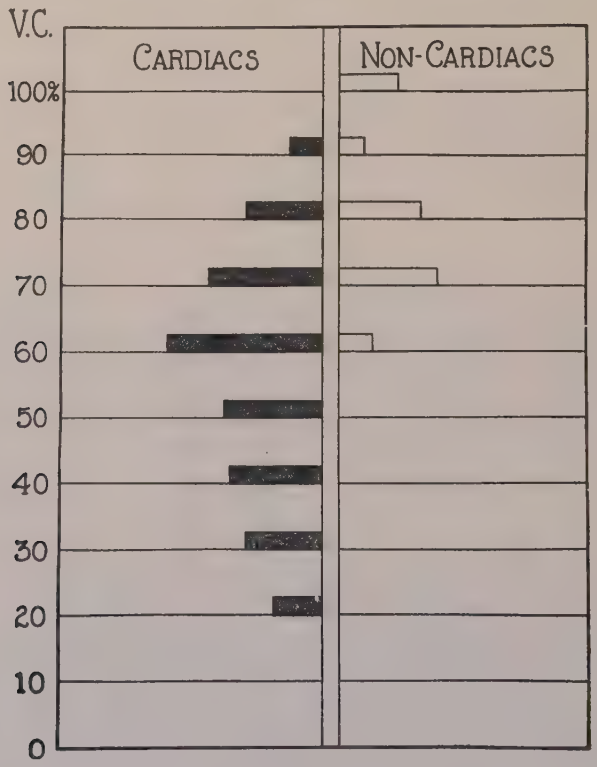

FIG. 6. COMPARISON OF THE VITAL CAPACITY IN A GROUP OF CARDIAC AND A GROUP OF NONCARDIAC CASES
After Ulrich and Nathanson

however, may show a gradual decrease in spite of treatment. Such findings usually warrant a bad prognosis.

Ulrich and Nathanson believe that possibly the greatest aid which the vital capacity test offers in cardiac cases is in relation to treatment: "It (1) gives us a measure of the results of treatment; (2) indicates the maximum point of

response to treatment; (3) establishes a cardiac tolerance for work; and (4) shows whether this cardiac tolerance for work is increasing or diminishing." They believe further that as in diabetes, where we frequently examine for glycosuria to determine whether the patient is remaining within his carbohydrate tolerance, so, also, the vital capacity test

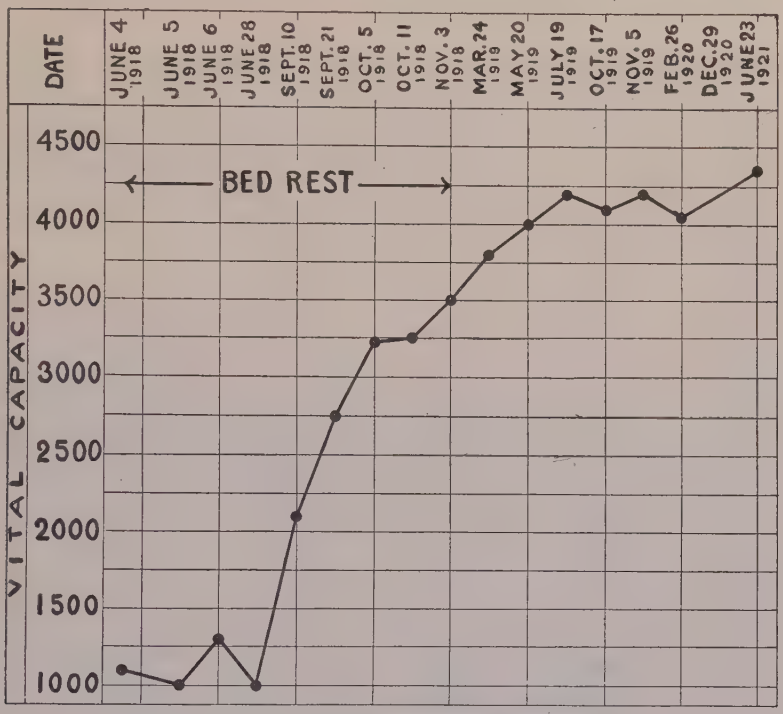

FIG. 7. CASE OF ACUTE MYOCARDITIS

Shows increase of vital capacity from 23 to 74 per cent while in bed. (After Pratt.)

may be applied frequently in cardiac cases to determine if the patient is remaining within his cardiac tolerance.

Pratt says, "The graphic records and charts of these and similar cases show the value of long continued observations of the vital capacity repeated over a long period of time in

measuring the increase or decrease of cardiac power. They will be found to be a distinct aid in the treatment and prognosis of heart disease."

Stewart found that, "Children may have a normal vital capacity even in the presence of a definite insufficiency of the mitral valves, and these individuals show little abnormal tendency to dyspnea on exertion. In more serious cases,

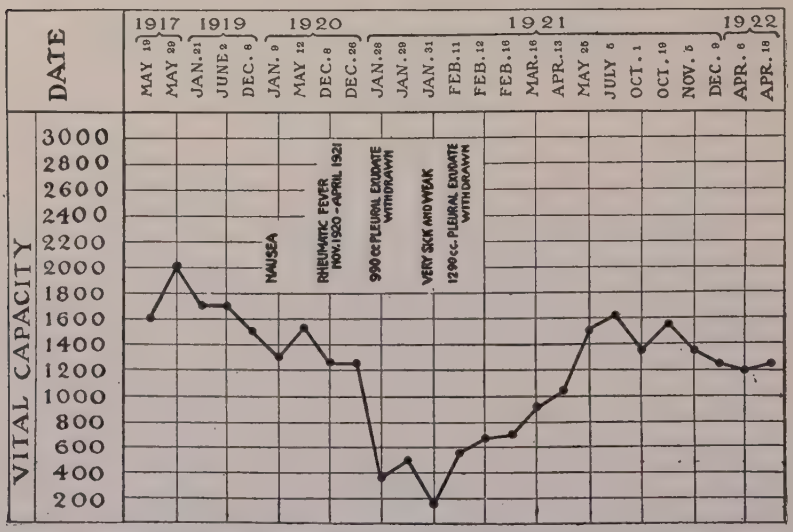

FIG. 8. VITAL CAPACITY RECORD OVER PERIOD OF FIVE YEARS IN A CASE OF SEVERE MITRAL STENOSIS

Fall of vital capacity during attach of acute rheumatic pericarditis with slow rise during convalescence. (After Pratt.)

the vital capacity is greatly reduced, and the tendency to respiratory embarrassment is proportional to the reduction in lung capacity. When the condition of the heart improves, the vital capacity gradually increases."

Table 2 and figures 5 to 10 show convincingly that cardiac disease is capable of reducing the vital lung capacity and that this test is a good guide in following the course of treatment.

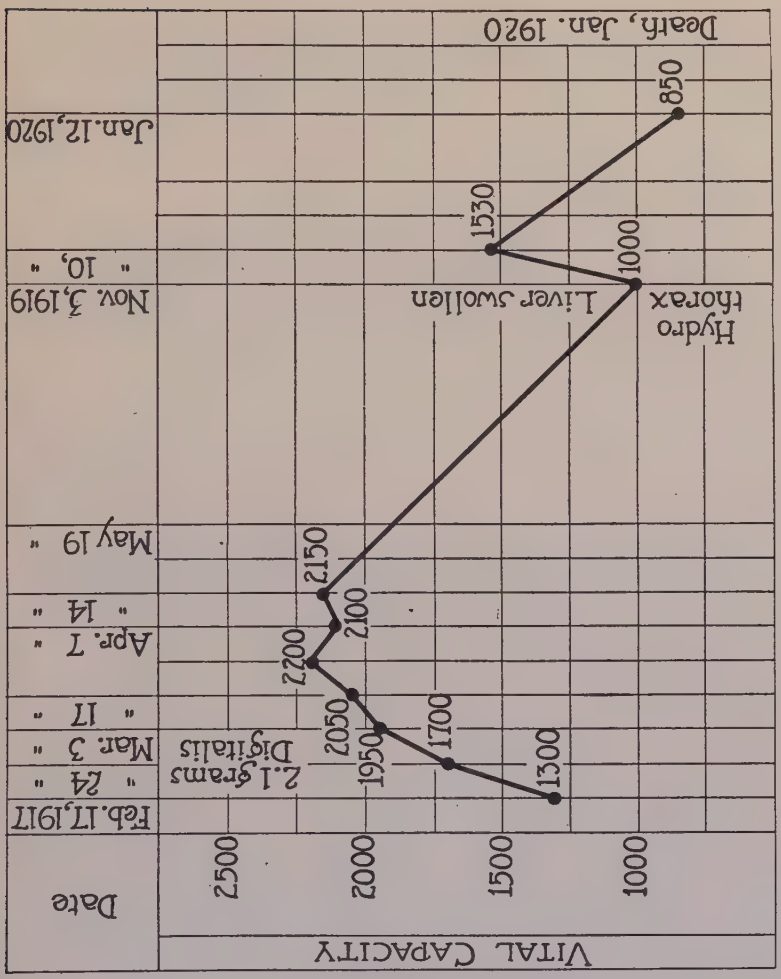

FIG. 9. CASE OF MITRAL STENOSIS WITH AURICULAR FIBRILLATION

Improvement from digitalis without bed rest. The vital capacity record shown covers a period of nearly three years. (After Pratt.)

Wilson and Edwards, after studying the vital capacity of children with heart disease, concluded that, "Vital capacity measurements show a close relation to the heart functional capacity, as gauged by the exercise tolerance. They cannot be considered quite so reliable an index of diminished capacity for physical activity in children with heart disease because of the wide variation obtained in the normals and the chance of other complicating factors."

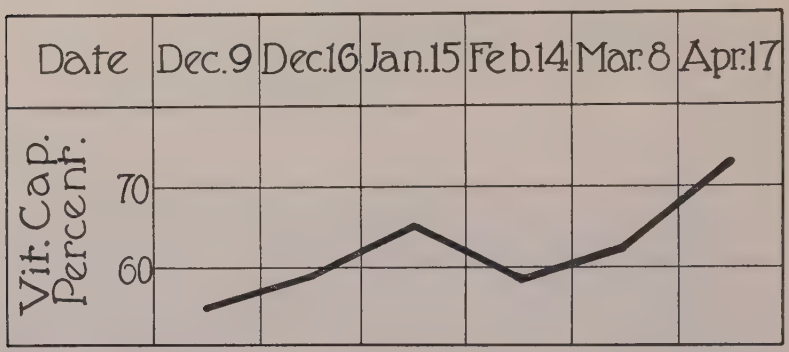

FIG. 10. FLUCTUATIONS IN THE VITAL CAPACITY CORRESPONDING TO CHANGES IN THE CLINICAL CONDITION

This is a case suffering from cardiac disease. (After Peabody and Wentworth.)

Hyperthyroidism. Peabody and Wentworth studied the effects of hyperthyroidism on the vital capacity of the lungs in 7 cases. They found it above 80 per cent in 5 cases and between 67 and 75 per cent in 2. They believed that dyspnea in hyperthyroidism may sometimes be the result of nervousness but is usually an indication of cardiac weakness. In their cases, "The decrease in vital capacity corresponded to the degree of the tendency to dyspnea." In 1923, Rabinowitch published a preliminary report of his investigations on this subject. The metabolic rate of his patients varied from +100 to +16 per cent while their vital capaci-

ties varied from 30 to 101 per cent of the theoretical normal. Figure 11 shows the striking relationship which he found to

TABLE 2

Number of cases, age, weight, standing height, vital capacity, normal vital capacity expected for corresponding standing height, per cent of deviation from normal, and note regarding dyspnea for boys and girls with mitral regurgitation

After Stewart

AVERAGE NUMBER OF CASES	AVERAGE AGE	AVERAGE NET WEIGHT	AVERAGE STANDING HEIGHT	AVERAGE VITAL CAPACITY	AVERAGE NORMAL VITAL CAPACITY FOR CORRESPONDING HEIGHT	AVERAGE DEVIATION FROM NORMAL	NOTES REGARDING DYSPNEA
	years	*pounds*	*cm.*	*cc.*	*cc.*	*per cent*	
Boys							
8	11	74.6	142	2,131	2,182	−2.4	No dyspnea on exertion
Girls							
17	12	77.4	144	1,939	2,005	−3.2	No dyspnea on exertion
Boys							
1	7	40	112	900	1,160	−22.4	Spleen enlarged; moderate dyspnea; râles in lungs
2	15	57	131	775	1,780	−56.5	Dyspnea pronounced
3	11	55	133	1,600	1,850	−13.5	Dyspnea on mild exertion
4	15	61	148	1,300	2,230	−41.7	Dyspnea on slight exertion
5	16	102	162	1,350	3,180	−57.5	Dyspnoic constantly
6	18	122	174	2,100	3,860	−45.6	Dyspnea on slight exertion
Girls							
1	9	40	121	950	1,360	−30.1	Dyspnoic
2	11	62	129	1,100	1,580	−30.4	Slight dyspnea
3	12	52	127	900	1,525	−41.0	Mild dyspnea on exertion
4	11	62	129	1,100	1,590	−30.8	Moderate dyspnea
5	13	87	145	900	2,100	−57.3	Severe dyspnea
6	13	80	146	1,250	2,150	−41.9	Moderate dyspnea
7	20	117	150	1,500	2,310	−35.1	Moderate dyspnea
8	14	83	152	1,200	2,400	−50.0	Dyspnea on slight exertion
9	16	120	163	1,950	2,830	−31.0	Considerable dyspnea

exist between increased basal metabolism and decreased vital lung capacity.

Lemon and Moersch studied the relationship between basal metabolism and vital capacity in 85 subjects with goiter. Although they found a decrease of vital capacity in most cases of hyperthyroidism, the relationship between basal metabolism and vital capacity was not sufficiently constant to be of much value. "As to the primary fundamental physicochemical cause of the decreased vital capacity in hyperthyroidism, we are still uncertain. However, we

FIG. 11. RELATION BETWEEN DECREASE IN VITAL CAPACITY AND DEGREE OF HYPERTHYROIDISM AS ESTIMATED BY BASAL METABOLIC RATE
After Rabinowitch

believe the secondary and direct cause is the cardiac inefficiency which arises from the primary source, the thyroid."

McKinlay reported the results of his studies on 57 cases, 48 of whom had exophthalmic goiter and 9 had toxic adenoma. He also used a control series of 48 cases of colloid goiter. After a splendid presentation of this subject, McKinlay is of the opinion that "in the great majority of cases the dyspnea and vital capacity reduction are proportional to the reduction of the functional capacity of the

heart." McKinlay also arrived at two important conclusions: "1. Marked reduction of the vital capacity of the lungs below 70 per cent occurred in a great majority of severely toxic cases of hyperthyroidism. 2. In the patients studied, reduced vital capacity of the lungs pointed more definitely to bad prognosis than did the degree of increase of basal metabolism."

Bronchial asthma. Staehelin and Schultze, Plesch, Peabody and Wentworth, and others, have reported vital capacity findings in adult patients suffering from asthma, in some cases considerably decreased, in others normal.

In a study by Myers, 20 persons suffering from bronchial asthma in which readings were made during acute attacks and at various intervals between, the vital capacity during acute attacks was found to be tremendously reduced, being in some cases as low as from 18 to 20 per cent of the normal. With the disappearance of the attack, however, the readings quickly returned to normal limits unless there existed some complication or other cause for a reduction. In most cases, the vital capacity remained normal so long as the chest was free from râles. In 4 cases in which asthma had extended over a period of many years and in which the vital capacity did not return to normal limits after the disappearance of the asthmatic attacks, physical and roentgen-ray examinations revealed definite evidence of emphysema which was apparently sufficient to account for the reduced capacity. In 3 patients, who were beyond the age of fifty, the reading did not again quite return to normal after the subsidence of the acute attacks. Since vital capacity decreases after the age of forty or fifty, the slight permanent reduction in these 3 cases was explainable on the age basis. The remaining cases showed vital capacities well within normal limits soon after the acute attacks had subsided.

In working with children, Stewart found that, "While bronchial asthma may cause an enormous reduction in the

TABLE 3

Number of cases, age, weight, standing height, vital capacity, normal vital capacity for corresponding standing height, per cent of deviation from normal and clinical notes for boys and girls subject to bronchial asthma

After Stewart

NUMBER OF CASES	AGE	GROSS WEIGHT	STANDING HEIGHT	VITAL CAPACITY	NORMAL VITAL CAPACITY FOR CORRESPONDING STANDING HEIGHT	DEVIATION FROM NORMAL	CLINICAL NOTES: DURATION OF DISEASE
	years	*pounds*	*cm.*	*cc.*		*per cent*	
Boys							
1	6	32	109	750	1,080	−30.6	Many râles present
2	6	39	113	775	1,190	−34.9	Many râles present
3	6	45	118	1,600	1,340	+19.4	No râles present
4	6	41	118	1,550	1,340	+15.7	No râles present
5	8	48	123	1,900	1,500	+26.7	No râles present; asthma for 6 years
6	7	48	123	1,450	1,500	−3.3	Few râles present; asthma for 4 years
7	8	57	124	800	1,530	−47.7	Many râles present
8	10	64	132	1,900	1,810	+5.0	Asthma for 3 years; no râles present
9	11	64	132	1,800	1,810	−0.5	
10	12	63	140	2,350	2,100	+11.9	Few râles present; asthma for 4 years
11	13	63	145	2,350	2,300	+2.2	Asthma for 9 years
12	11	72	146	1,950	2,340	−16.7	Asthma for 2 years; no râles present
13	14	104	155	3,200	2,760	+15 9	Eight years
Girls							
1	7	38	119	900	1,300	−30.8	Many râles present; 3 years
2	9	46	120	1,275	1,330	−4.1	No râles present
3	9	50	130	1,800	1,620	+11.1	Few râles present
4	13	65		2,500			No râles present; 7 years

vital capacity immediately following an acute attack, nevertheless, the reduction promptly disappears as the symptoms

subside. Even in children subject to the disease for several years, there is apparently no permanent reduction in the vital capacity of the lungs." Table 3 shows that there is no uniform reduction in vital capacity in children subject to bronchial asthma.

Emphysema unquestionably reduces the vital capacity of the lungs. It has been shown that vital capacity is greatly reduced during the acute attacks of asthma. Between the acute attacks, however, it should return approximately to normal. If this does not occur, the

TABLE 4

Shows vital capacity percentages of groups of cases suffering from diseases of the bronchi

After Myers and Cady

	NUMBER OF CASES	VITAL CAPACITY
		per cent
Negative cases (x-ray and physical signs and symptoms)	101	103.7
Acute bronchitis (physical signs and symptoms)	12	100.0
Chronic bronchitis (x-ray or physical signs and symptoms)	156	101.1
Peribronchial infiltration—unilateral (x-ray)	34	101.1
Peribronchial infiltration—bilateral (x-ray)	128	101.0
Total	431	

development of hypertrophic emphysema should be strongly suspected. The compensatory emphysema, which occurs in bronchopneumonia and tuberculosis, possibly plays some part in the reduction of vital capacity in patients suffering from these diseases.

Bronchitis. In 156 cases of chronic bronchitis, Myers and Cady found that the average vital capacity was 101.1 per cent of the theoretical normal (table 4). The lowest reading observed, however, was 69 per cent of the normal. In this case, as well as in a few others with low vital capacity read-

ings, there was very profuse expectoration and it was believed that the low readings were due to mucous obstruction of some of the bronchial tubes.

Peabody and Wentworth found that the vital capacity may be reduced to a considerable extent during an attack of *acute bronchitis*. In children suffering from acute bronchitis, Stewart observed a temporary reduction in vital capacity. He points out that the presence of considerable mucus in the tubes often provokes coughing toward the end of expiration and thus prevents complete expiration.

Pleurisy. In acute fibrinous pleurisy the vital capacity may appear to be greatly decreased because of the severe pain which makes it impossible for the patient to take a deep breath. Severe acute fibrinous pleurisy, accompanying such conditions as pneumonia, pulmonary abscess or pulmonary carcinoma, often lowers the reading very greatly.

In a recent study Myers and Rice found the average vital lung capacity in fifty-four cases of chronic fibrous pleurisy to be 94.1 per cent while in twenty-six cases of healed empyema it was 91 per cent of the theoretical normal.

In cases of sero-fibrinous pleurisy, the reduction in vital capacity depends to a large extent upon the amount of fluid in the pleural cavity. In purulent pleurisy Graham showed that it is greatly reduced. "That this reduction does not depend merely upon the presence of the fluid exudate in the pleural cavity is shown by the fact that an appreciable increase in the vital capacity occurs only gradually after the removal of the exudate."

It has been shown recently by Sturgis, Peabody and Hall that when the chest is bound down with a swathe, the vital capacity may be reduced approximately 50 per cent and the maximum minute-volume is reduced about 50 per cent. In

this work it was demonstrated that the subjective sensation of dyspnea increases as the actual minute-volume encroaches upon the maximum minute-volume. The condition produced in this work is believed to closely simulate that in pleurisy with effusion where the vital capacity is reduced. "The essential cause of the variation which may occur in the maximum minute-volume is an alteration in the vital capacity of the lungs and this may, therefore, be regarded as a practical index of the maximum minute-volume."

Pneumothorax, whether artificial or spontaneous, causes a decrease in vital capacity. In studying chronic pulmonary disease, one occasionally finds a case in which vital capacity quite suddenly drops several hundred cubic centimeters. When this occurs, spontaneous pneumothorax should be suspected. In artificial pneumothorax the vital capacity reduction apparently does not depend entirely upon the amount of gas injected into the pleural cavity. For instance, an individual with a vital capacity of 3000 cc., after having 500 cc. of gas injected, may blow more or less than 2500 cc. In a small series of cases of pneumothorax reported by Myers the average vital capacity was found to be 49 per cent of the normal.

Pulmonary abscess, bronchiectasis and new growths are responsible also for reduction in vital capacity, the degree of which depends upon the extent of involvement and the severity of the affection.

A case recently reported by McKean shows how carcinoma of the lungs reduces the vital capacity. This patient's theoretical normal was 3120 cc., but on admission to the hospital her actual vital capacity was 1200 cc. and ten days before death it was reduced to 800 cc. The reduction served as a "distinct guide in diagnosing the scope of the

lung pathology, and this was further borne out by the continued fall as the process advanced clinically and roentgenologically." The change in vital capacity furnished the first real evidence of the extent of the progress of the intrathoracic process which was later demonstrated in the autopsy room. "Postmortem examination revealed "massive adenocarcinoma of the liver (primary) with metastases to the lung, pleurae, mediastinal lymph-nodes and kidney."

Pneumonia. Peabody and Wentworth reported 5 cases convalescing from pneumonia in whom the vital capacity varied between 71 to 114 per cent of the normal. After a study of some 20 cases of pneumonia Myers stated that there is probably no acute disease of the respiratory tract which so reduces the vital capacity from the beginning as pneumonia. The vital capacity test is, therefore, a valuable aid in early diagnosis. It has been possible to take vital capacity readings on patients suffering from acute respiratory infections (other than pneumonia) and other acute diseases with symptoms closely simulating those of pneumonia and to select those developing pneumonia from the vital capacity test alone. In pneumonia the vital capacity is reduced tremendously (fig. 12) and the reduction is not consistent with the extent of involvement, as those with disease limited to one lobe or even a part of one lobe may have a vital capacity as low as those with much more extensive involvement. Usually, the maximum reduction is reached on or near the day of the crisis. After this time, if convalescence is undisturbed, the vital capacity supplies a valuable index as to the clearing up of the lesions. In cases of unresolved pneumonia or in the development of such complications as lung abscess or empyema the vital capacity increases very slowly or not at all (fig. 13). This test is extremely valuable

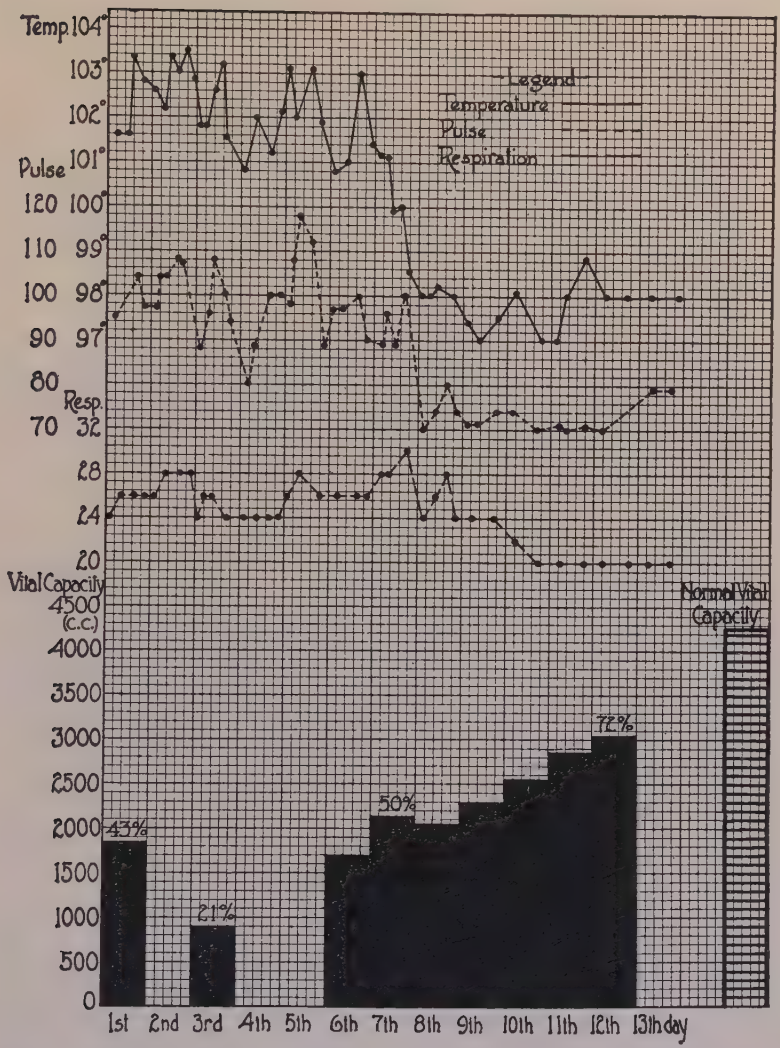

FIG. 12. TEMPERATURE, PULSE, RESPIRATION AND VITAL CAPACITY CURVES IN THE CASE OF A MAN, AGED FORTY, SUFFERING FROM LOBAR PNEUMONIA INVOLVING THE LEFT LOWER LOBE

Left hospital on the twelth day with the vital capacity approximately 72 per cent of the normal. (After Myers.)

in determining when it is safe for a patient convalescing from pneumonia to become active. Patients are too often discharged from hospital and returned to active lives before their lung capacities are consistent with such activities. It

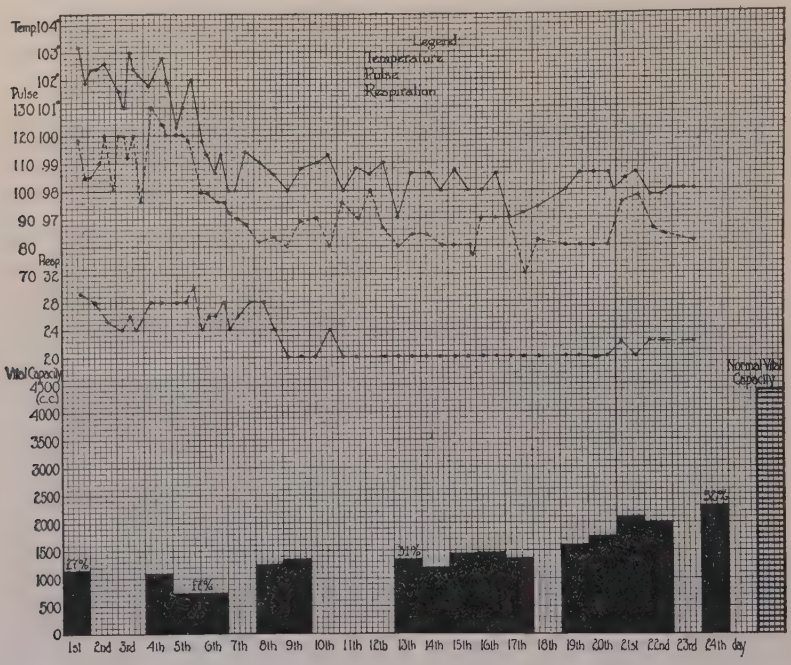

FIG. 13. TEMPERATURE, PULSE, RESPIRATION AND VITAL CAPACITY CURVES IN THE CASE OF A MAN, AGED TWENTY-THREE, SUFFERING FROM LOBAR PNEUMONIA INVOLVING THE ENTIRE RIGHT LUNG AND THE UPPER LOBE OF THE LEFT LUNG

The lowest vital capacity recorded was 17 per cent of the normal which occurred on the fifth and sixth days. This is a case with delayed resolution. Patient left hospital on the twenty-fourth day with a vital capacity of 52 per cent of the normal. (After Myers.)

is recommended strongly that no patient undertake an active life either in the hospital or the home until the vital capacity has been restored to within 90 per cent of the normal.

A study of 12 cases of pneumonia led Arnett and Kornblum to believe that the spirometer has the following uses in this disease:

"(1) As an adjunct to the usual, clinical pulse, temperature and respiration record, the vital capacity graph assist in visualizing the course of the disease.

"(2) After the crises, a failure of the vital capacity to increase rapidly and steadily may point towards a complication, while the presence of such an increase argues against the latter.

"(3) Frequent accurate vital capacity readings before and after operation for empyema are apparently valuable in indicating the success or failure of the operation.

"(4) An extremely low vital capacity may assist in differentiating pneumonia from diseases which do not lead to such a marked reduction."

In children (table 5) Stewart found that lobar pneumonia effects the vital capacity of the lungs in a manner very similar to that above described for adults. He says, "During the course of lobar pneumonia the vital capacity rapidly undergoes an enormous reduction, even in cases free from pleurisy. The reduction is altogether out of proportion to the extent of the pneumonic process in the lungs. Following the crisis, the vital capacity gradually returns to normal in a comparatively short time. Physical signs of the disease, however, may disappear before the normal vital capacity is reached. In complicated cases the return of vital capacity to normal may be greatly delayed."

Pulmonary tuberculosis. In 1846, Hutchinson reported that he had been greatly aided by the vital capacity test in the diagnosis of pulmonary tuberculosis. Following Hutchinson's work, Wintrich, Simon, Arnold, Fabius,

Schneevogl, Muller, Waldenburg, Cornet and others found the vital capacity definitely reduced by pulmonary tuberculosis. Shepard, after using the vital capacity test very

TABLE 5

Number of cases, age, standing height, weight, initial vital capacity, day of illness, vital capacity at each succeeding reading, normal vital capacity for corresponding standing height, per cent of deviation from the normal for boys and girls with lobar pneumonia

After Stewart

NUMBER	STANDING HEIGHT	NET WEIGHT	INITIAL VITAL CAPACITY AND DAY OF ILLNESS	VITAL CAPACITY AT EACH SUCCEEDING READING						NORMAL VITAL CAPACITY FOR CORRESPONDING STANDING HEIGHT	DEVIATION FROM THE NORMAL
	cm.	*pounds*									*per cent*
Boys			4	5	6*	9	12				
1	118	50	350	450	800	1,050	1,250			1,340	−6.7
			6	8*	14						
2	116	51	750	1,000	1,225					1,280	−4 3
			3	4	5	7*	8	9	10		
			4	7*	8	9	14	50	71		
3	134	65	400	600	700	900	750	800	1,200	1,880	−36.2
			3	13	20	25					
4	135	59	850	1,350	1,600	1,700				1,920	−11.5
Girls			1	6	7*	10	12				
5	106	39	150	750	775	800	850			950	−10.6
			7*	9	12	14	15	16			
6	123		700	750	800	900	1,000	1,100		1,410	−22.0
			4	6*	8	10					
7	43		350	1,000	1,100	1,250				2,030	−38.4
			10	12	15	19					
8	133	62	800	900	1,300	1,550				1,510	+2.6
			6	9	12	16	20	23	26		
9	155	960	300	675	1,000	1,500	1,650	2,000	2,050	2,520	−18.7

* Day of crisis.

extensively in the diagnosis of tuberculosis during the past forty years, states that he has found it of very great value. Garvin, Lundsgaard and Van Slyke, in addition to other

valuable findings, learned that in minimal tuberculosis the vital capacity was decreased as a result of an increased amount of residual air, while in moderately advanced cases the decrease was chiefly due to a diminished total capacity. Dreyer and Burrell, from a study of 200 cases of pulmonary tuberculosis, found the vital capacity test valuable in diagnosis, classification and in following the results of treatment. Their conclusions deserve to be quoted:

"1. In cases of pulmonary tuberculosis there is a definite decrease in vital capacity as compared with what should be normal for any individual, taking into account the class in which this individual should be placed according to occupation and mode of life.

"2. An improvement in the clinical condition of the patient is found to be accompanied by an increased vital capacity, while an advance of the disease results in a decrease in vital capacity. The vital capacity, therefore, gives a valuable quantitative measure of the benefit, if any, which a patient receives as a result of treatment.

"3. The determination of the vital capacity is useful for the classification of cases of pulmonary tuberculosis, because it is possible by this means numerically to express the injury to health (e.g., degree of toxemia) which otherwise would depend on the individual interpretation of physical signs by different observers. In this connection, it should be noted that classification by physical signs alone may place a patient nearing death from an acute lesion in a high category; while another patient, with satisfactory fibrosis and extensive cavitation, likely to live for several years, may be placed in the lowest category.

"4. As an aid to diagnosis a single or repeated examination of the vital capacity of doubtful cases will also prove

useful. If a normal vital capacity is found in such cases, the patient is most unlikely to be suffering from pulmonary tuberculosis; whereas, if the vital capacity is much decreased the patient should be suspected, though it must always be borne in mind that other diseases may also cause a lowering of the vital capacity.

"5. Finally, a systematic study of the vital capacity in its proper relationship to body size has given important information as to the beneficial effects of different treatments of pulmonary tuberculosis, and has made it possible to distinguish quantitatively the degrees of improvement."

Subsequent studies by Dreyer and Burrell have substantiated these conclusions. The findings of these writers and of others were confirmed by Wittich, Myers and Jennings who reported the results of their work on 82 tuberculous patients.

Piery and Boisseau in discussing the maximum respiratory volume per unit of time and the vital capacity are of the opinion that the manometric mask of Pech and the spirometers, through the information which they give concerning the evolution of pulmonary tuberculosis, and by virtue of the ease with which they may be handled, warrant their use in the future in the practical treatment of tuberculosis.

In a series of recent papers dealing with vital capacity in pulmonary tuberculosis more data have been added to show that the vital capacity test is valuable, not only in diagnosis and prognosis, but also in studying the results of treatment. Table 4 shows that in 162 cases of peribronchial infiltration revealed by the x-ray many of whom were diagnosed peribronchial tuberculosis by the roentgenologists the average vital capacity is approximately 101 per cent of the theoretical normal.

A point of considerable interest is that many of the pulmonary cases presented in table 6 did not have clinical tuberculosis; in other words, they fall into that group in Brown's classification of demonstrable non-clinical cases. Many of them gave no history of illness. Of this entire group some were examined because they were applying for

TABLE 6

Cases (717) grouped according to chest x-ray findings

After Myers and Rice

	NUMBER OF CASES	AVERAGE VITAL CAPACITY	CLINICAL NUMBER OF CASES	TUBERCULOSIS AVERAGE VITAL CAPACITY	CLINICAL SIGNIFICANCE QUESTIONABLE		NON CLINICAL TUBERCULOSIS	
					Number of cases	Average vital capacity	Number of cases	Average vital capacity
Negative	112	104.1						
Pleurisy (chronic fibrous)	54	94.1						
Empyema (healed)	26	91.0						
Pulmonary tuberculosis:								
A. Unilateral:								
1. Above the first rib	203	98.7	42	85.5	9	89.0	152	103.0
2. Not more than one lobe	94	96.5	38	97.5	7	92.1	49	103.7
3. More than one lobe	22	65.6	22	65.6	None			
B. Bilateral:								
1. Above the first ribs	70	95.5	30	84.3	8	98.7	32	102.8
2. Not more than two lobes	90	80.9	69	74.4	4	106.0	17	104.8
3. More than two lobes	46	53.8	46	53.8	None			
Total	717							

insurance or compensation, some were examined because they believe in periodic physical examinations and others were examined because they possessed definite symptoms. Of the entire group of 717 cases, 203 fell into the "above the first rib" group. The average vital capacity for this group was found to be 98.7 per cent of the theoretical normal.

This figure is only slightly below that of 101 cases with negative x-ray findings. Of the 203 cases, however, only 42 had clinical disease. Their average vital capacity was found to be 85.5 per cent of the normal or more than 18 per cent lower than the group of 101 negative cases. Of the 203 cases, there were 9 in whom the clinical significance was question-

TABLE 7

Cases (773) of pulmonary tuberculosis grouped according to symptoms and physical signs

After Myers and Rice

	NUMBER OF CASES	AVERAGE VITAL CAPACITY
Negative	338	102.4
Diagnosis reserved	47	98.7
Pulmonary tuberculosis:		
Min. A	98	90.0
B	32	81.3
C	6	77.4
Moderately advanced:		
A	68	83.0
B	66	74.1
C	11	69.5
Far advanced:		
A	34	53.0
B	52	50.7
C	21	42.6
Total	773	

able at the time of the examination. They presented an average vital capacity of 89 per cent of the normal. Among the 203 cases 152 fell into the class of demonstrable non-clinical disease. It is gratifying to find that this group possessed an average vital capacity approximately as high as the group of negative cases. It is obvious, therefore, that it is never fair to the vital capacity test to present averages from cases grouped according to the x-ray findings alone.

The clinical significance of disease is of utmost importance. This holds true throughout the remainder of table 6 which is self-explanatory. Small areas of non-clinical disease effect the vital capacity of the lungs very little or not at all. On the other hand, our study leads us to believe that clinical tuberculosis practically always reduces vital capacity. When the vital capacity readings, symptoms and physical findings were correlated (table 7), it was found that when

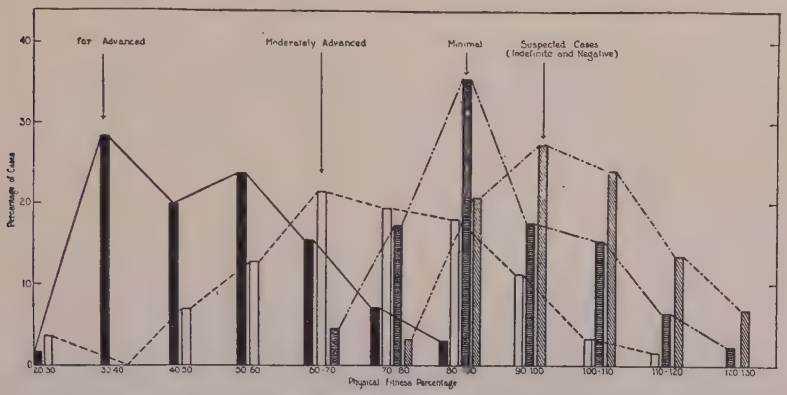

FIG. 14. PERCENTAGE FREQUENCY CURVES SHOWING GROUPS OF CASES IN THE VARIOUS STAGES OF PULMONARY TUBERCULOSIS

These curves show that in a general way the vital capacity of the patient decreases as the physical signs increase and the stage of disease advances. (After Myers.)

the physical signs and symptoms were negative the average vital capacity was 102.4 per cent while in cases of pulmonary tuberculosis, with physical signs of parenchymatous involvement, the average vital capacity was found to be decreased as the physical signs and symptoms increased (table 7 and figs. 14 and 15).

Cameron recently reported the results of his observations on 198 tuberculous patients. He found the correlation between the vital lung capacity and the anatomic changes

in the lungs so close as to show convincingly that vital capacity readings deserve a definite place as a supplementary method of diagnosis and prognosis.

Piery and Boisseau after making vital capacity observations upon fifty-five men suffering from tuberculosis stated

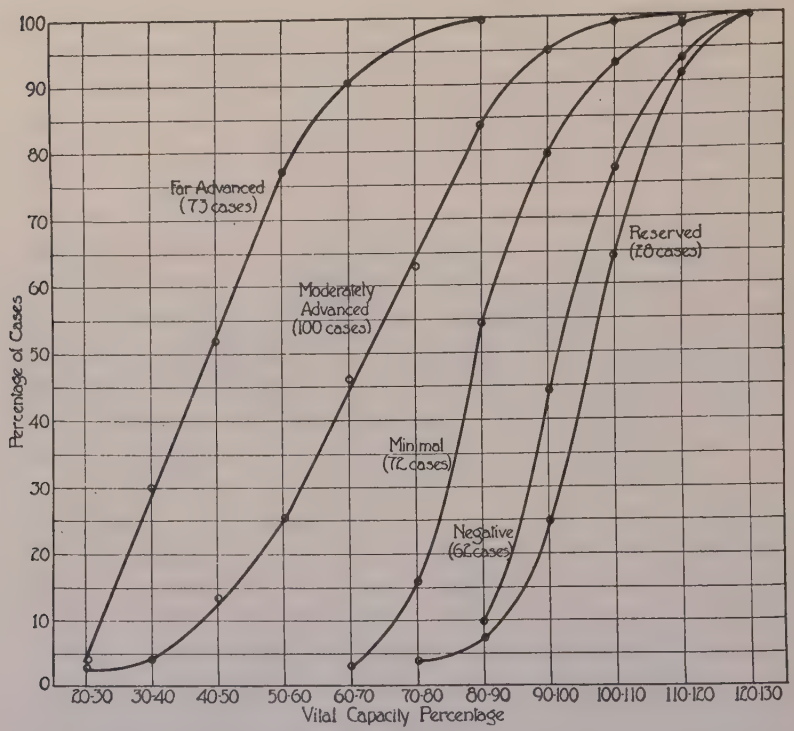

FIG. 15. CURVES SHOWING PERCENTAGE OF CASES IN EACH STAGE OF PULMONARY TUBERCULOSIS PLOTTED AGAINST THE VITAL CAPACITY
After Myers

that a study of the maximum volume of air respired, per unit of time and of vital capacity, furnishes information of the greatest clinical interest in tuberculosis, provided the investigations are carried out in series in the same patient.

Contrary to what one might expect, those who have made studies of the vital capacity of the tuberculous state that they have seen no harm result to patients from this test.

Not enough work has been done to determine the effects of pneumonoconiosis on vital capacity. Figure 16 shows the average vital capacity in 80 bituminuous coal miners to be only slightly below 100 per cent of the normal until the

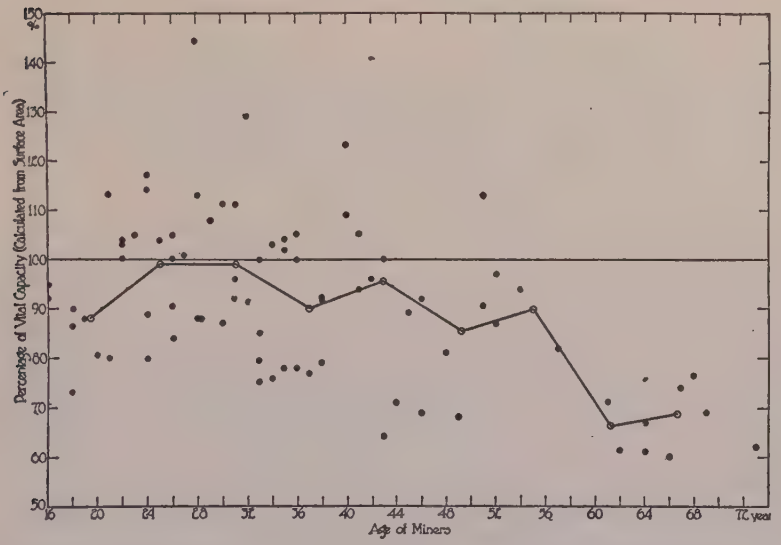

FIG. 16. PERCENTAGE OF VITAL CAPACITY PLOTTED AGAINST AGE OF EIGHTY BITUMINOUS COAL MINERS

After Myers

age of forty-six years. After this age the capacity is considerably decreased but the age factor must be given due credit for its part in this reduction.

The effects of past diseases on vital capacity. In the past there has been considerable speculation as to whether vital capacity, once reduced by certain diseases, ever returns to the normal. Recently, Shepard made quite an extensive

study of this subject in which he used 611 male University students with histories of influenza, pneumonia, pleurisy, pulmonary tuberculosis or heart disease (figs. 17 to 21).

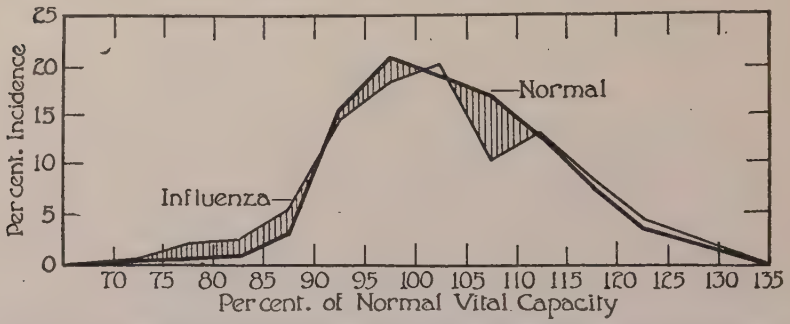

FIG. 17. CURVES DRAWN TO SHOW THE REMAINING EFFECT OF EPIDEMIC INFLUENZA ON VITAL CAPACITY

Note the slight lowering and shifting to the left of the influenza curve, indicating a slight reduction in vital capacity in the group as a whole. (After Shepard.)

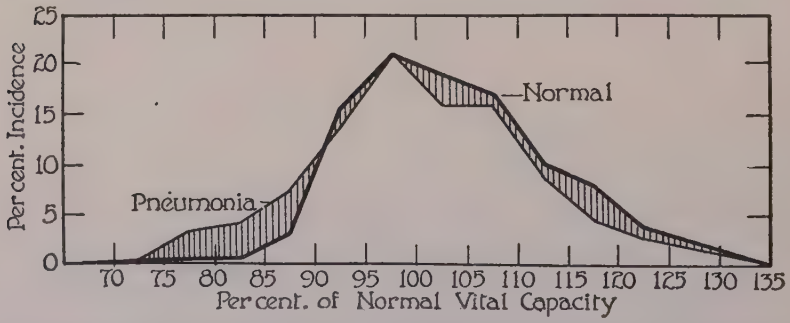

FIG. 18. CURVES DRAWN TO SHOW THE REMAINING EFFECT OF PNEUMONIA ON VITAL CAPACITY

Note the slight but definite lowering of the pneumonia curve and a shifting to the left, a little more marked in this group than in the influenza series. (After Shepard.)

He compared the vital capacities of these students with 2821 without histories of such diseases. From his study, Shepard concluded that, "Influenza and pneumonia appear to

lower the vital capacity of a large group, although the change is slight. Pneumonia varies but slightly in its effect on the vital capacity, according to the age at which it is contracted.

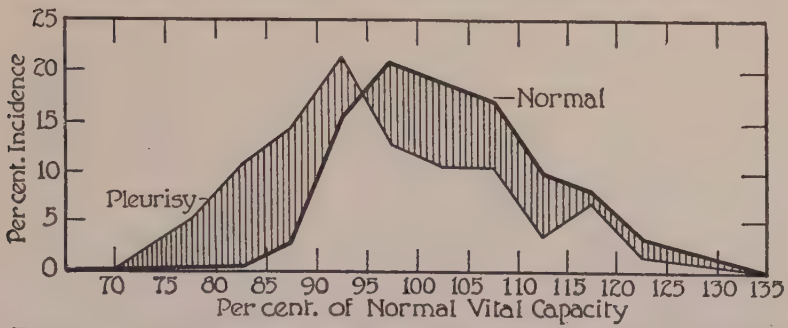

FIG. 19. CURVES DRAWN TO SHOW THE REMAINING EFFECT OF PLEURISY ON VITAL CAPACITY

Note the marked lowering of the height of the pleurisy curve and a greater shifting to the left than in the influenza or pneumonia series. (After Shepard.)

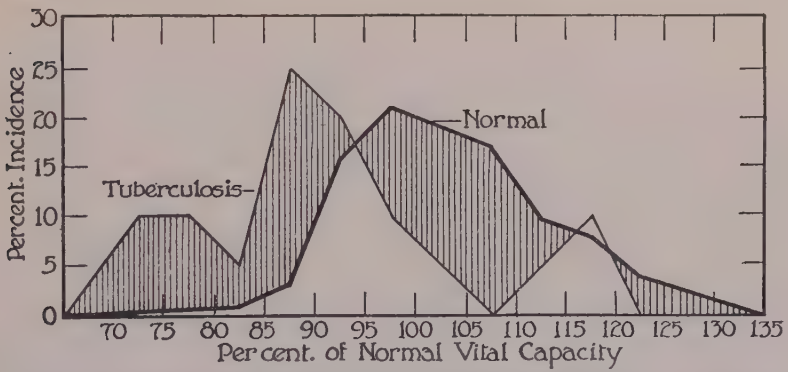

FIG. 20. CURVES DRAWN TO SHOW THE REMAINING EFFECT OF PULMONARY TUBERCULOSIS ON VITAL CAPACITY

Note that the shifting to the left of the tuberculosis curve is much greater than in figures 17, 18 and 19. (After Shepard.)

When pleurisy, pneumonia, pulmonary tuberculosis or organic heart disease is included among the past diseases of a group of persons, there is apparently a definite and

probably a permanent lowering of the vital capacity of the group as a whole."

What causes the vital capacity to be reduced? This question has been asked frequently, and a number of explanations have been offered. Bash, Siebeck, Ulrich and Nathanson, and Barron call attention to the fact that early in impaired cardiac function there is a statis and enlargement of the capillaries in the walls of the lung alveolae, which changes they believe affect the elasticity and expansibility of the

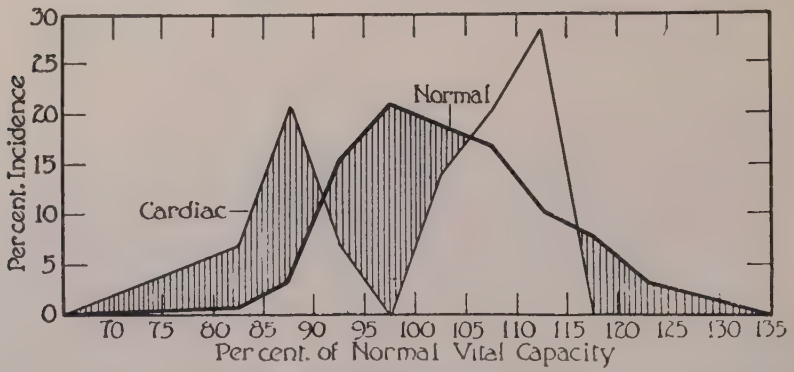

FIG. 21. CURVES DRAWN TO SHOW THE REMAINING EFFECT OF CARDIAC DISEASE ON VITAL CAPACITY

Note that the shifting to the left of the cardiac curve is quite marked indicating a definite lowering of vital capacity. (After Shepard.)

alveolar walls. And though Mackenzie and others have considered râles at the bases of the lungs as one of the earliest evidences of cardiac decompensation, these observers further point out that "a reduction in vital capacity, although an expression of the same engorgement process, occurs, however, at an earlier stage and may, therefore, be taken as an earlier evidence of cardiac impairment." The work of Drinker, Peabody and Blumgart has shown that intravascular blood is capable of obstructing and encroaching upon the alveolar spaces, thus reducing their capacity.

In pulmonary tuberculosis it has been known for some time that although a small lesion exists the expansion of the chest and the movements of the diaphragm on the same side may be considerably limited. It has been shown also that a severe lesion even if very small may reduce the vital capacity more than an extensive lesion of a milder nature. Garvin, Lundsgaard and Van Slyke have shown that in such cases the reduced vital capacity is due to increased residual air. These findings would suggest that a change occurs in the walls of the alveoli which limits the use of the affected lung. In moderately and far advanced pulmonary tuberculosis the destruction of tissue undoubtedly plays a considerable rôle in diminishing the vital capacity. In fact, Garvin, Lundsgaard and Van Slyke found that in moderately advanced pulmonary tuberculosis the reduction in vital capacity is due largely to a diminished total capacity.

In *pneumonia* it has been found that the reduction in vital capacity is not proportionate to the extent of involvement. For instance, in one with a small area of involvement there may be a vital capacity reduction as great as in another with consolidation of one or more entire lobes. Perhaps the compensatory emphysema in the lobules adjacent to the affected ones and the congestion of the alveolar capillaries, together with the limited movement of the diaphragm on the side of the involvement, accounts for the greater part of the reduction.

In *asthma* the marked reduction in vital capacity during acute attacks is apparently due to obstruction caused by constriction of the bronchial musculature. Obstruction of the tubes by an accumulation of mucus undoubtedly is responsible for the greater part of the reduction in *bronchitis*.

It was suggested by Peabody and Wentworth that the

reduction in patients convalescing from pneumonia is due possibly to weakness following toxemia, and may be found in patients convalescing from any acute toxic condition. My observations on the vital capacity of 60 patients suffering from and convalescing from *paratyphoid* fever showed that the vital capacity is reduced below normal limits in a very small percentage of the cases and, in these cases, the reduction could be explained on other bases such as development of pleurisy or pneumonia. During convalescence, the vital capacity of the uncomplicated cases was found to be within normal limits. In this series of cases fever and rapid pulse had apparently little or no effect upon the vital capacity.

It has been stated that the vital capacity test is a good index as to physical fitness, but some of the more recent work suggests that a correlation of vital capacity with certain measurements of the body is an index of physical fitness only in relation to the heart or lungs. Peabody and Sturgis, studying the effects of general weakness on the vital capacity of the lungs, found 12 patients suffering from anemia all of whom gave history of weakness, and some in an extreme form. The average vital lung capacity of these patients was 88.7 per cent of the normal, while the lowest was 74 per cent of the normal. Of another patient they report: "Test made on thirty-sixth day of typhoid fever, second day of normal temperature. Could not register grip-testing apparatus with either hand; had a vital capacity of 86 per cent of the normal." It would appear that these figures could hardly represent the true physical fitness of the patients studied.

Peabody and Sturgis made a further study of the effect of fatigue of the muscles of respiration on the vital capacity.

They attempted to produce this fatigue by taking vital capacity readings every fifteen seconds for ten minutes. The individuals used in this work were suffering from cardiac disease or pernicious anemia. It is interesting to note that they showed a vital capacity at the end of the experiment as great as at the beginning.

It appears, therefore, that patients suffering from a disease outside the heart and lungs which causes extreme weakness have a reduction in physical fitness greater than the vital capacity test indicates.

SUMMARY

Patients with vital capacities 15 per cent or more below the normal should be most carefully examined for disease conditions interfering directly or indirectly with the functions of the heart or lungs.

Conditions of no present clinical significance which may reduce the vital capacity are: Old pleural adhesions, deformities of the thorax and ossification of the costal cartilages. In addition to these, malingering, lack of coöperation and will power must be considered. There is a small group of persons with low vital capacities in whom no cause has been found.

Conditions of present clinical significance which reduce the vital capacity are: Cardiac disease, hyperthyroidism, emphysema, asthma, pleurisy, pneumothorax, pulmonary abscess, new growths, pneumonia, and pulmonary tuberculosis. Vital capacity readings therefore render considerable aid in the diagnosis, the guidance of treatment and the prognosis of these conditions. At present it is most valuable in cardiac disease, pleurisy, pneumonia and pulmonary tuberculosis.

When pleurisy, pneumonia, pulmonary tuberculosis or organic heart disease is included among the past diseases of a group of persons, there is apparently a definite and probably a permanent lowering of the vital capacity of the group as a whole.

In cardiac disease it is believed that the vital capacity is reduced because of a stasis and enlargement of the capillaries in the walls of the lung alveolae which effect the elasticity and expansibility of the alveolar walls. In minimal pulmonary tuberculosis it is believed that the reduction in vital capacity is due to increased residual air, while in moderately and far advanced cases the destruction of tissue undoubtedly plays a considerable rôle in the vital capacity reduction.

CHAPTER IV

Some Limitations and Uses of the Vital Lung Capacity Test

It is a well known fact that any new or revived test is likely to meet with opposition from those who have not used it and therefore know little or nothing about it. On the other hand, those who perhaps specialize a little in the use of a test may become so overenthusiastic as to make exorbitant claims for it. It is only fair that now after considerable data have accrued through numerous original investigations, the real limitations and true uses of the vital lung capacity test should be as far as possible presented.

Like every other test and phase of examinations, as made today, the vital capacity test is not infallible. It is true that normal standards have not yet been perfected for people of all races, occupations and ages.

Individual variation offers one of its greatest limitations. One who may have ordinarily a vital capacity of 125 per cent of theoretical normal may develop a disease which materially reduces his vital capacity, and yet the readings may be well within the generally accepted normal limits. This difficulty may be overcome if the vital capacity of individuals while in a normal state of health is recorded.

In the differential diagnosis of chest diseases the vital capacity test gives us very little aid. Probably the only help we receive from it is in differentiating pneumonia from certain other acute diseases. It also serves as excellent differential evidence between pneumonia and acute appendicitis.

Contrary to fairly recent teaching it is apparently a test of physical fitness only insofar as the heart or lungs are involved.

On the other hand its uses are many and very definite. It can tell us roughly, yet quickly, whether there is involvement of much clinical significance affecting the heart or lungs directly or indirectly. It aids in differentiating between pneumonia and certain other acute diseases of the respiratory tract.

It gives valuable information regarding the severity of lesions especially tuberculous lesions.

In dealing with acute infections, outside the heart and lungs, the vital capacity test is valuable in detecting developing complications such as pneumonia.

The test is a good index also as to the effects of treatment of diseases of heart or lungs. If improvement occurs the vital capacity will often show an increase before any change can be detected by other methods of examination. On the other hand, if the condition remains stationary or progresses, the vital capacity will remain unchanged or show an actual decrease.

After making a careful study of the Importance of Vital Capacity in Thoracic Surgery, Graham arrived at the following conclusions:

"Determination of the vital capacity by means of a spirometer, when used in connection with the mathematical expression given in the text, will indicate approximately the maximum opening in the chest wall compatible with life, if the mediastinum is not already stabilized by adhesions and induration. If such observations are made before establishing open drainage in cases of empyema or before any thoracic operation, doubtless many lives will be

saved. Both theoretical conclusions and actual observations show that in empyema the vital capacity is greatly reduced. That this reduction does not depend merely on the presence of the fluid exudate in the pleural cavity is shown by the fact that an appreciable increase in the vital capacity occurs only gradually after the removal of the exudate. This fact is of importance in being an additional argument against the establishment of an open drainage during the acute pneumonic stage of an empyema when the vital capacity is so low as to approximate the tidal air requirement. Extensive thoracoplastic operations result in apparently a permanent marked reduction in the vital capacity. They should be employed therefore, only in the rarest instances and only after other methods have been given an intelligent trial for at least many months."

After making a study of the vital capacity of 579 surgical cases, estimating the risk and later comparing their estimate with the surgeons estimation of the risks and later observing the post operative course Lemon and Moerch arrived at the following conclusion:

"For routine purposes the determination of the operative risk from the surgeon's opinion is probably on the whole a more satisfactory estimate than that obtained by means of the vital capacity readings: However, if the surgeon does not have the benefit of experience, or the assistance of an experienced internist in making such an estimate, especially in questionable cardiac and pulmonary conditions, vital capacity determinations may be of the greatest aid. From whatever cause, the closer the approximation of vital capacity to tidal air, the graver will the risk become. When low readings are obtained, the surgeon would do well to institute preoperative measures and to make fur-

ther observations before attempting operation." Eloesser says, "One should test the vital capacity in pulmonary tuberculosis before doing a thoracoplastic collapse. If it is low, one should operate in several stages and do a less extensive collapse than when it is fairly within normal limits." Andrus says, "The vital capacity constitutes, in a sense, the cardiorespiratory reserve, or at least one factor of it may be taken as such, and strengthening this reserve in treating thoracic conditions, just as the building up of the cardiac reserve in the treatment of cardiac conditions, means giving the patient a larger factor of safety." Yates has also recently called attention to the significance of the vital capacity test in thoracic surgery.

Recently Myers and Bailey made a study of the value of the vital capacity test in administering artificial pneumothorax treatments. In our report of this work in the American Review of Tuberculosis we stated that we have been interested in determining how much a given amount of air injected into the pleural cavity reduced the vital lung capacity. In order to determine this we have taken the vital lung capacity immediately before and immediately after the pneumothorax treatments. In almost every instance we have found that the vital capacity reduction is not equal to the amount of air injected into pleural cavity. For example, one patient who had pneumothorax treatment over a period of more than two years was found to have a vital capacity of 2500 cc. just before a refill; 500 cc. of air was injected into the pleural cavity, after which her vital capacity was found to be 2100 cc. At a later time her vital capacity was 2300 cc. before an injection of 400 cc. of air. Her capacity was reduced to only 2150 cc. In all of our cases the amount of air injected into the pleural cavity

was determined by the manometer reading. When this reading reached zero or became very faintly positive the injection of gas was discontinued. There was only an occasional case with very extensive adhesions in which only a small pocket of air could be injected. When we used definitely positive pressure in such cases the amount of pressure used apparently had very little effect on the vital capacity.

One occasionally meets with a patient who has very extensive pleural adhesions; indeed, the visceral and parietal layers of pleura may be almost completely adherent. In such cases the needle may pass through the visceral pleura into the lung without the operator being aware of the presence of adhesions. The oscillations on the manometer may be slight and the inexperienced operator may introduce air directly into the lung. Good-sized quantities may be recorded, and without x-ray control the operator may believe that the air has reached the pleural cavity. In such cases the vital capacity taken just before and just after an artificial-pneumothorax attempt will furnish one with much information. One will find that, although 400 or 500 cc. of air have passed through the needle, the patient's vital lung capacity has not decreased. This error should be avoided because the negative pressure on the manometer will in most cases inform one as to the location of the needle. However, the inexperienced operator may be misled by slight oscillations when the needle is within the lung tissue.

In another group of 4 cases we have been able to follow the vital capacity readings throughout the course of pneumothorax treatment. Figure 22 shows that a patient with a vital capacity of 3200 cc. before the initial pneumothorax

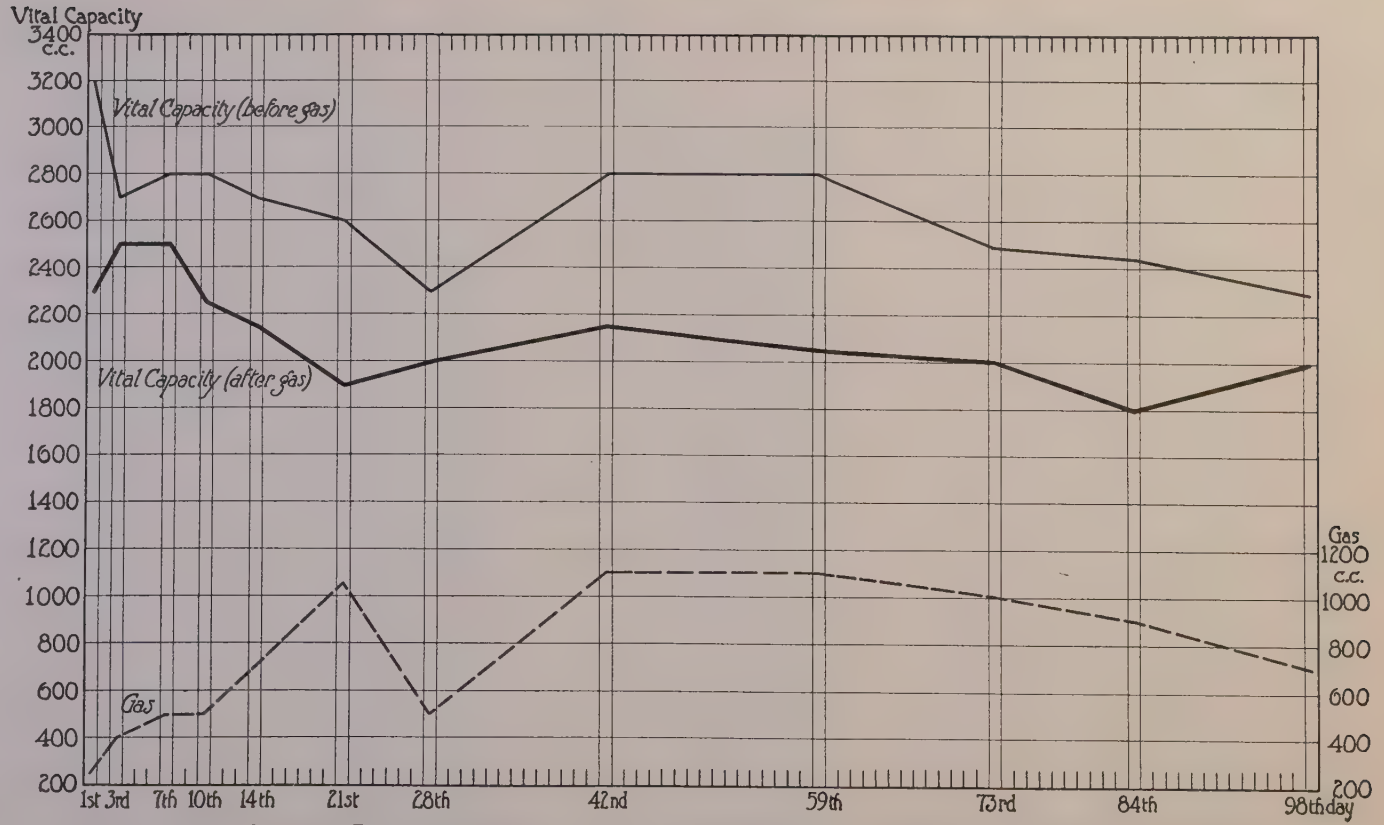

FIG. 22. VITAL CAPACITY BEFORE AND AFTER ARTIFICIAL PNEUMOTHORAX TREATMENTS TOGETHER WITH AMOUNT OF GAS ADMINISTERED EACH TIME OVER A PERIOD OF NINETY-EIGHT DAYS

Note the marked decrease in vital capacity following the initial treatment. (After Myers and Bailey)

treatment presented a vital capacity of only 2300 cc. after the first injection of 250 cc. of air. Although this did not occur in each case it seemed to be a fact of considerable significance; for example, if one is dealing with a patient who has a very low vital capacity, even by the introduction of a small amount of air, the vital capacity may be reduced so as to approach the tidal air. Obviously such patients would suffer much dyspnea and discomfort. Therefore the vital capacity taken before the initial injection of air may be found of great value in determining the amount of air which can safely be injected. After the first treatment figure 22 shows that subsequent injections reduced the vital capacity only slightly and never to the extent of the amount of air injected. Therefore, if the patient has a low vital lung capacity, an amount as small as 50 or 100 cc. of air may be introduced and repeated within twenty-four hours.

In one patient who had a vital capacity of only 1000 cc. before artificial-pneumothorax treatment was begun, marked dyspnea was experienced after the injection of approximately 175 cc. of air. We feel that it would have been much better and safer to have injected no more than 50 or 75 cc. at first in this instance.

Apparently the extent of involvement in the good or better lung affects considerably the reduction of vital capacity; for example, figure 23 shows graphically the effects of artificial pneumothorax upon vital capacity in a patient who had extensive disease on one side with no active process on the opposite side. In this case the injection of gas, bringing about a collapse of the badly involved lung, in the beginning affected the vital capacity only very slightly. It would appear that in such cases the compensatory action

of the better lung had already been well established before artificial pneumothorax was begun.

Figure 24 illustrates a case with moderate disease on one

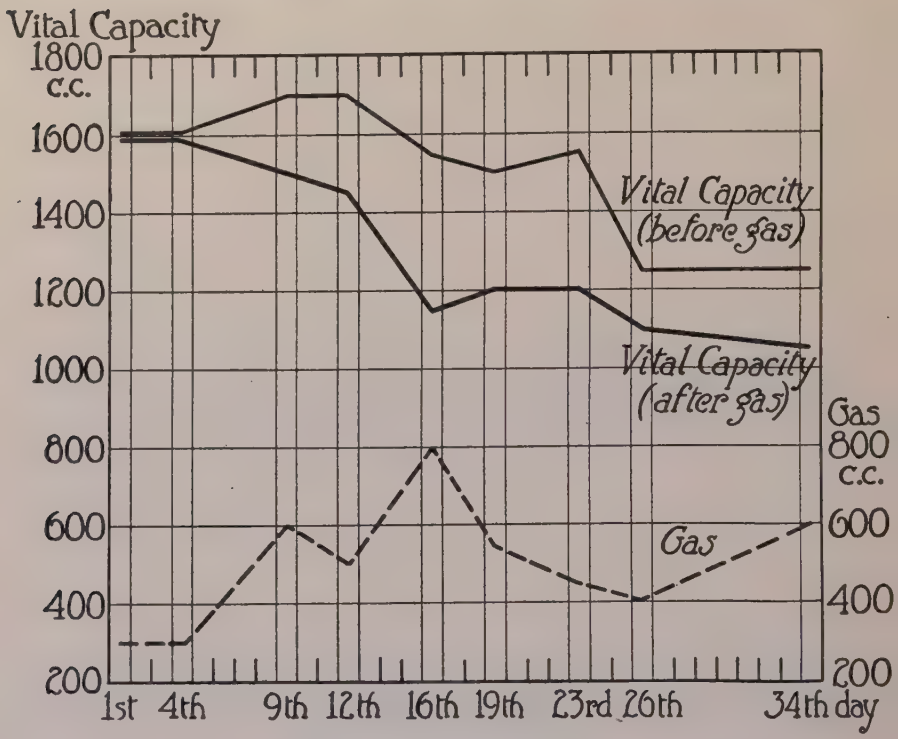

FIG. 23. VITAL CAPACITY BEFORE AND AFTER ARTIFICIAL PNEUMOTHORAX TREATMENTS TOGETHER WITH AMOUNT OF GAS ADMINISTERED EACH TIME OVER A PERIOD OF THIRTY-FOUR DAYS

Note the slight effect of the first injection of gas upon the vital capacity. (After Myers and Bailey.)

side and slight disease on the opposite side. Here we find no marked initial decrease such as is recorded in figure 22.

We have also felt that routine vital capacity readings are valuable in determining the condition of the better lung.

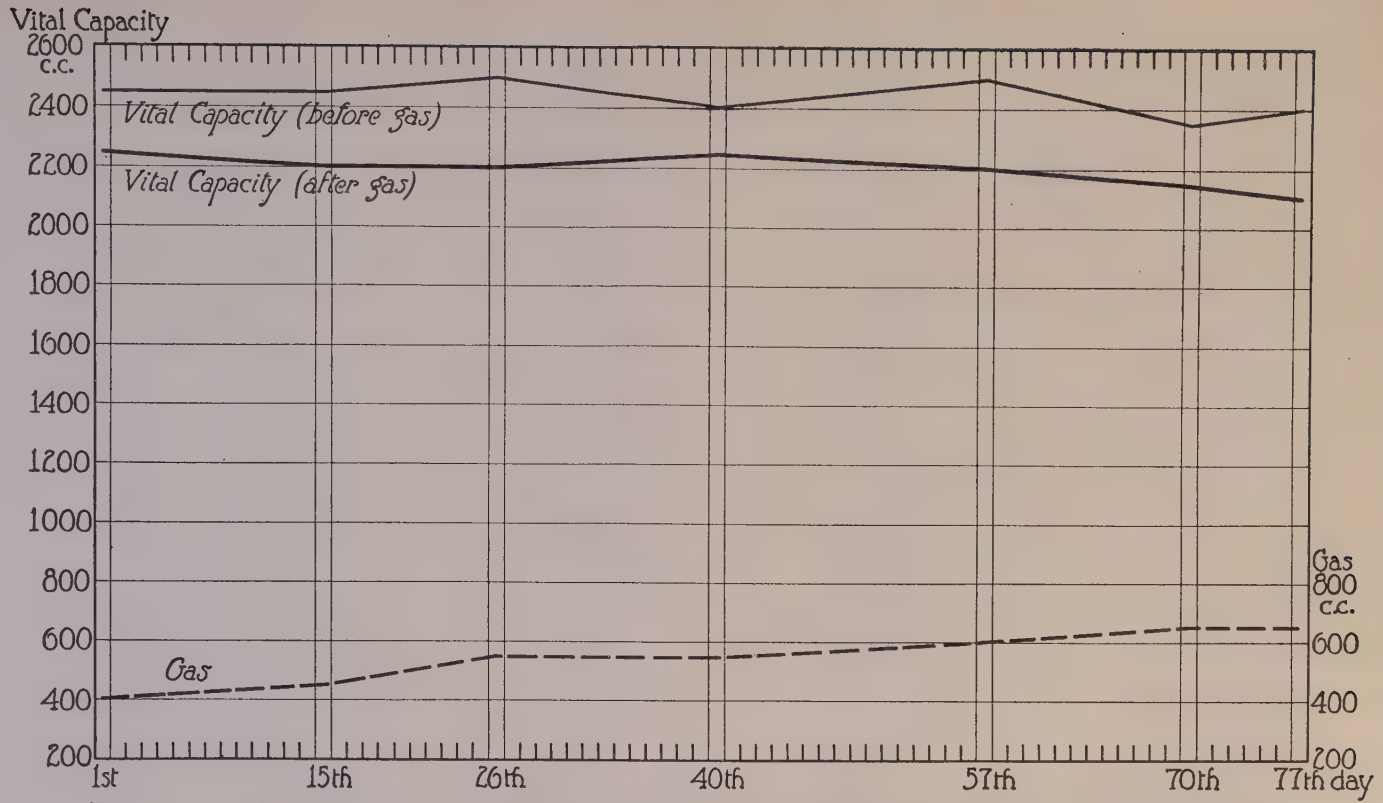

FIG. 24. VITAL CAPACITY BEFORE AND AFTER ARTIFICIAL PNEUMOTHORAX TREATMENTS TOGETHER WITH AMOUNT OF GAS ADMINISTERED EACH TIME OVER A PERIOD OF SEVENTY-SEVEN DAYS

After Myers and Bailey

In cases with one lung well collapsed we have found that the readings after the injection of air sufficient to bring the manometer reading to zero were quite constant from time to time. Thus, a patient with a vital capacity of 2500 cc. after one treatment will have approximately the same vital capacity after subsequent treatments, provided the opposite lung is holding up well. In cases in which the opposite lung is showing definite extension of the disease this is not true, but, on the contrary, the vital capacity shows a gradual reduction from time to time.

Although our group of cases includes only two that had extrapleural thoracoplasty, they have very definitely borne out this statement. One of these patients, who had an extensive process in the left upper lobe, had been on artificial pneumothorax treatment with exceedingly good results. This was at the time when it was believed that pneumothorax should not be continued over a very long period. Her physician considered her lung as healed and allowed it to expand completely. The following winter she contracted influenza, following which her tuberculous process became reactivated. Although artificial pneumothorax was attempted many times after this, it was impossible to inject more than 150 cc. of air at any time because of adhesions. Her vital lung capacity was found to be 1200 cc. Since that time she has had extrapleural thoracoplasty in three stages. Segments of all the ribs on the left side above the eleventh were removed. Now her vital lung capacity is only 800 cc. Nevertheless, she has at the present time an excellent working capacity and shows no tendency toward dyspnea as long as she does light work.

In the second case, unfortunately, no vital capacity reading was recorded before the extrapleural thoracoplasty

was done. This operation was performed under local anesthesia in two stages. Segments of all the ribs above the eleventh were removed. At the present time this patient's general condition is excellent, yet her vital lung capacity is 1400 cc., which is 45 per cent of her theoretical normal.

Piery and Boisseau found a study of maximum respiratory volume per unit of time and vital capacity determinations well worth while in four cases of artificial pneumothorax.

I do not wish to leave any reader with the impression that the vital capacity test is infallible or that it should replace any part of the physical or x-ray examinations as they are used today. But the laboratory, physical and x-ray examinations are all subject to error. In fact, diagnosis of disease rarely should be made on a single phase of an examination, but all possible information should be obtained from every available source before a patient is told that disease does or does not exist in his body. In such a complete examination the vital lung capacity test is fully entitled to a place. When these facts become more generally known, patients will refuse to be satisfied with single test applied or with "slip shod" or short cut methods of examination, and will insist that their examinations be honestly, conscientiously and completely done.

Not only is the vital capacity test valuable in diagnosis of disease and in studying the effects of treatment of disease, but it may be made extremely useful in industrial and preventive medicine. Industrial organizations will find that routine vital capacity determinations on all persons entering their employ will greatly aid in the detection of certain diseases which might otherwise be overlooked. Again if such readings are kept on record they

will often be found valuable for comparison with subsequent readings taken at times when employees may be developing early disease of the heart or lungs, or when claims for compensation are made because of physical disabilities supposedly developed while in the company's employ.

Many colleges and universities are now making vital capacity readings a routine procedure in the entrance examinations of all students registered. Already clinicians have found such records valuable. They are being made also in many schools and the matter of making the readings a part of the routine physical examination of school children was discussed favorably at a recent convention of the National Education Association.

After devoting some time to the study of the significance of serial vital capacity readings in the diagnosis and treatment guidance of certain diseases of the chest I have cited cases and made the following statements, published in the American Review of Tuberculosis. For a long time body weight has been looked upon as a good health criterion. We know that it is materially changed by certain disease conditions—some resulting in increase but the majority in decrease. Although this is true, one meets many people who know nothing of their actual body weights. On the other hand, there are many persons who, because of past public health education, pay a great deal of attention to their weights and become concerned when deviations from the usual are observed. The importance of encouraging all persons to keep body weight records is obvious.

An equally valuable good health criterion is the vital capacity of the lungs which is easily determined and is remarkably constant from year to year in adults before the ages of forty-five except in the presence of disease involving

directly or indirectly the heart or lungs. Therefore, if ones actual vital capacity is known it may serve as an excellent standard of judging the condition of the heart and lungs from time to time. In children, the vital capacity increases with body growth, but there is such a definite correlation between body size and vital capacity in childhood that one is able to anticipate with a reasonable degree of accuracy the

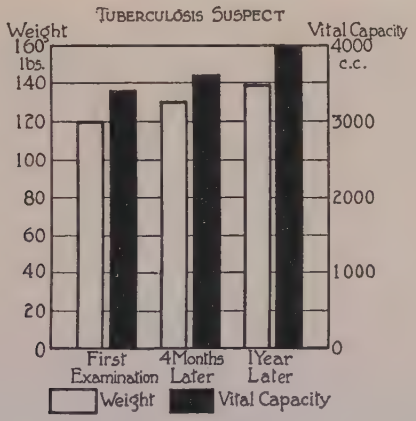

FIG. 25. VITAL CAPACITY READINGS TAKEN SERIALLY OVER A CONSIDERABLE PERIOD OF TIME

The patient was suspected of having pulmonary tuberculosis. The normal increase in vital capacity with growth of the body is of practical significance. (After Myers.)

increase in vital capacity with a given increase in body size. So long as the vital capacity increase is consistent with the increase in body size there is no cause for alarm. The following cases illustrate this point. A girl of fifteen years had recently lost a twin sister from pulmonary tuberculosis. Her parents being very solicitous of her health demanded that her lungs be carefully examined from time to time. On the first examination her weight was 121 pounds and

her vital capacity was 2900 cc. No phase of the physical or x-ray examination revealed any evidence of disease of the lungs or heart. Three years later her weight had increased to 145 pounds and her vital capacity had increased to 3500 cc. Re-examination of the heart and lungs revealed no evidence of disease. The confirmatory evidence obtained from the vital capacity readings in this case was very helpful.

A boy of fifteen years had been told by his family physician that an examination revealed slight evidence of early pulmonary tuberculosis. Soon after this examination the boy's weight was found to be 120 pounds and his vital capacity was 3400 cc. (fig. 25). Four months later his weight had increased to 130 pounds and his vital capacity to 3600 cc. One year after this his weight was found to be 138 pounds and his vital capacity 4000 cc. Examination at that time revealed no evidence of pulmonary tuberculosis.

Another case is that of a school boy of fourteen years who developed empyema. His weight was 76 pounds and his vital capacity was 2000 cc. After about ten weeks of treatment his body weight had increased to 86 pounds and the vital capacity to 2400 cc. Two years later his weight was found to be 115 pounds and his vital capacity 2700 cc. Approximately four months after this the weight had increased to 126 pounds and the vital capacity to 3200 cc.

If, on the other hand, the vital capacity of the lungs of growing children decreases or even remains constant in the presence of definite increase in body size the evidence is sufficient to warrant most careful examination and subsequent observation for disease of the lungs or heart.

As previously stated, because of individual variation some normal persons have vital capacities considerably higher,

and others lower than the theoretical normal. Obviously, in such cases the vital capacity test cannot be of great value in diagnosis when a single reading is taken. However, if previous readings taken when such persons were in good health are available this test is of tremendous value when examining for disease. The following cases are cited to illustrate this point:

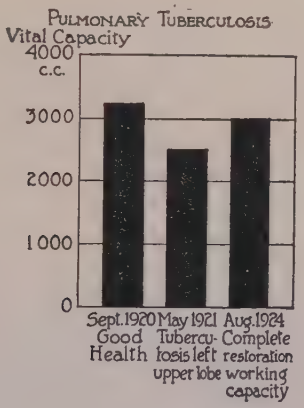

Fig. 26. Vital Capacity Readings Taken Serially Beginning When the Patient Was in Good Health Continuing Through an Attack of Pulmonary Tuberculosis and Ending with the Patients Working Capacity Restored.

After Myers

A young woman of twenty years was enrolled as a freshman medical student when without warning she had a frank hemorrhage. Physical and x-ray examination made in December, 1920, revealed a very definite parenchymatous involvement of the left upper lobe while the laboratory examination revealed numerous tubercle bacilli in the sputum. Her vital lung capacity was not taken until May,

1921, when it was found to be 2500 cc. (fig. 26). A record was available of an examination made in September, 1920, which revealed no evidence of disease of the lungs. At that time her vital capacity was 3276 cc. After treatment resulted in the arrest of her tuberculosis this patient completed an arts and science course majoring in chemistry. She is now employed as a teacher. An examination on August 9, 1924, revealed definite evidence of the old disease area but no evidence of activity of the lesion. Her vital capacity was found to have increased to 3000 cc. She is now classified as an apparently cured case. This case illustrates how definitely disease of the lungs decreases vital capacity and also how the reduced capacity increases with the healing of the disease.

A young woman complained of the recent development of symptoms suggesting pulmonary tuberculosis. An examination in May, 1921, revealed definite evidence of slight disease involving the apices of both lungs. At that time her vital capacity was 2400 cc. A record which had been made in September, 1919, showed that the examination then revealed no evidence of pulmonary disease. At that time her vital capacity was 2686 cc. The actual loss in capacity of approximately 300 cc. was of definite significance in her case.

A young man reported for examination because of a recent exposure to tuberculosis. Very definite involvement of a moderately advanced nature was found in both upper lobes in April, 1921. The diagnosis was confirmed by the presence of tubercle bacilli in the sputum. His vital capacity was found to be 3400 cc. (fig. 27). A record made in September, 1919, showed his lungs to be clear at that time. Then his vital capacity was 3670 cc. It was imnormal persons have vital capacities considerably higher,

possible to convince this patient that strict and prolonged treatment was necessary in his case. He continued doing some work and finally decided to "go west." He did this but one year later (April, 1922) on his return an examination revealed extension of his tuberculous processes. At this time his lung capacity was 3100 cc. He then decided to go to a sanatorium but died in less than one year. This case illustrates the value of the vital capacity test not only in diagnosis but also in following the progress of the disease.

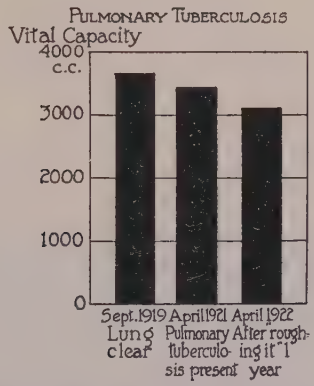

Fig. 27. Vital Capacity Readings Taken Serially Beginning When the Patient Was in Good Health and Continuing until Pulmonary Tuberculosis Developed into the Advanced Stage. After Myers

A man of about thirty years had recently lost weight. He also complained of fever and malaise. After having a frank hemorrhage he requested an examination of the chest in December, 1920. This revealed pulmonary tuberculosis involving the middle and lower lobes of the right lung. In May, 1921, his vital capacity was 3300 cc. However, artificial pneumothorax had been begun before this reading

was taken. A record of an examination made in September, 1912, while he was a student revealed no evidence of chest disease. At that time his vital capacity was 4635 cc.

A young man who had worked his way through college and had become very popular in a social way developed symptoms which led him to suspect tuberculosis a few weeks before graduation. An examination made in May, 1924, revealed unmistakable tuberculosis involving the left upper lobe. His vital capacity was found to be 3700 cc. This young man had been examined in October, 1917, when his chest was reported entirely negative. At that time his vital capacity was 4587 cc.

A pharmacist became acutely ill and was told that she had influenza. After the symptoms failed to disappear she was examined in June, 1923, for pulmonary tuberculosis which was found to involve the left upper lobe. Her vital capacity was 2300 cc. I had examined this patient and requested stereoscopic plates in April, 1921, at which time no evidence of pulmonary pathology was revealed. She then had no complaints but recently had been exposed to tuberculosis. Her vital capacity was 3000 cc. With the development of tuberculosis her vital capacity had decreased 700 cc.

A minister reported for an examination of the lungs which revealed a pleural effusion on the right side. He stated that three weeks before he had had pneumonia and since that time had noticed considerable dyspnea. Fluid removed for diagnosis was clear. This patient's vital capacity was 2300 cc. An examination which I had made eight months before revealed no evidence of chest pathology and the vital capacity was 5000 cc. After the second examination when the vital capacity was so definitely reduced he was

made an absolute bed patient. After approximately ten weeks in bed the vital capacity had increased to 2800 cc. In the next week the capacity increased to 2950 cc., the next week to 3050 and the third week to 3275 cc. Two weeks later this patient came in with the complaint that he had contracted a severe cold. The physical signs in his chest had increased and his vital capacity had decreased to 2850 cc. Soon after this patient moved to another city and although I have had correspondence with his present physician I have never been able to obtain further lung capacity readings. This case also illustrates well how the vital capacity is of value not only in diagnosis but also in following the progress of disease.

The time is at hand when all persons should know their actual vital lung capacities, just as they should know their actual heights and weights. Any person who loses several pounds in weight has reason to seek the cause; so, also, any person whose actual lung capacity decreases more than 10 or 15 per cent has just cause for seeking investigation. Many persons would become familiar with their actual vital lung capacities if spirometers were made available as weighing scales are. To install accurate spirometers and tables with normal vital capacities and weights in many places where they would be available to the public, would be an excellent public health measure. To be sure, some method would have to be devised to insure a sterilized mouth piece for each person. Perhaps one could be made of heavy waxed paper and used as the paper drinking cup is today. The taking of one's vital capacity and its comparison with the theoretic normal is so fascinating as to insure extensive use of spirometers if they were made available to the public. Moreover the readings obtained

from scales, and spirometers are so concrete as to be convincing to the ordinary citizen. I am convinced that such a method would result in bringing many who suffer from heart or lung disease for definite diagnosis and treatment long before they would, otherwise, present themselves. Thus many more persons would arrive while in the curable stages of disease.

SUMMARY

Because of individual variation normal vital capacity standards can never be made applicable to all persons. Therefore, our normal standards like normal weight standards will always be somewhat limited in their usefulness.

Several conditions lower vital capacity to about the same degree, therefore, the test is not of great value in differential diagnosis except in pneumonia which apparently causes a greater reduction than any other acute condition.

In known conditions such as cardiac disease, pneumonia, pulmonary tuberculosis, vital capacity readings are of definite value in determining the severity of lesions, detecting beginning complications, guiding the treatment and rendering prognosis.

Thoracic surgeons have found that vital capacity readings are valuable in estimating the operative risk. Indeed an eminent surgeon has said: "If such observations are made before establishing open drainage in cases of empyema or before any thoracic operation, doubtless many lives will be saved."

CHAPTER V

Measurements and Instruments Used in the Vital Capacity Test

It has been shown that there are fairly constant correlations between the vital capacity of the lungs and certain other measurements of the body such as standing height sitting height, body surface area and chest circumference. The most approved methods of obtaining the vital capacity and other necessary measurements, together with the instruments in common use, will be considered.

Vital capacity. Many forms of spirometers are obtainable, but all of them are divisible into two classes or types, namely, the dry type and the wet or water type. The dry type of spirometer is easily transported, but most instruments of this type need to be inspected rather frequently to make sure that they are recording accurately. The instrument which Hutchinson invented (fig. 28) belonged to the water type. It has been simplified considerably (fig. 29) since Hutchinson's time and none has been devised which is more accurate and reliable. The subject is instructed to take the deepest possible inspiration, then through the mouth piece, exhale as much as possible. Three trials are allowed and the highest reading is recorded as the vital capacity.

Standing height. This measurement is taken in the usual manner. Shoes should be removed or the proper deductions made for them.

Body weight. The body weight must be taken without clothing, or the proper deduction made for the clothing. In

addition to the actual net body weight, one should know the percentage of the theoretical normal which the actual weight represents. The theoretical normal body weight of an individual has been much discussed in the last few years. In the tables prepared by the Association of Life Insurance

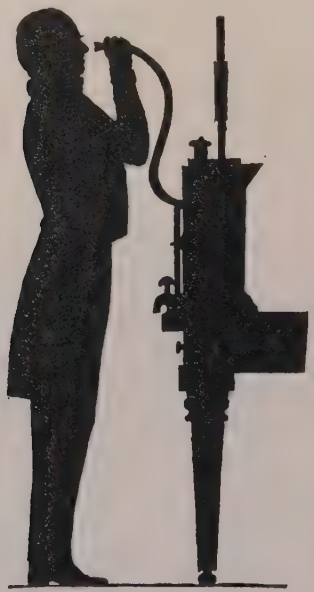

FIG. 28 FIG. 29

FIG. 28. AN ILLUSTRATION OF THE SPIROMETER WHICH HUTCHINSON USED AND DESCRIBED IN 1846
After Myers

FIG. 29. AN ILLUSTRATION OF THE MODERN SANBORN SPIROMETER
After Myers

Medical Directors and the Actuarial Society of America, the body weight is correlated with standing height and age (tables 8 and 9). The figures given in the tables are the average weights of large numbers of individuals of the same age and the same height. It is obvious, therefore, that

TABLE 8

Standard weight according to height and age—men

After Association of Life Insurance Medical Directors and the Actuarial Society of America

AGE	5 FEET	5 FEET 1 INCH	5 FEET 2 INCHES	5 FEET 3 INCHES	5 FEET 4 INCHES	5 FEET 5 INCHES	5 FEET 6 INCHES	5 FEET 7 INCHES	5 FEET 8 INCHES	5 FEET 9 INCHES	5 FEET 10 INCHES	5 FEET 11 INCHES	6 FEET	6 FEET 1 INCH	6 FEET 2 INCHES	6 FEET 3 INCHES	6 FEET 4 INCHES	6 FEET 5 INCHES
15	107	109	112	115	118	122	126	130	134	138	142	147	152	157	162	167	172	177
16	109	111	114	117	120	124	128	132	136	140	144	149	154	159	164	169	174	179
17	111	113	116	119	122	126	130	134	138	142	146	151	156	161	166	171	176	181
18	113	115	118	121	124	128	132	136	140	144	148	153	158	163	168	173	178	183
19	115	117	120	123	126	130	134	138	142	146	150	155	160	165	170	175	180	185
20	117	119	122	125	128	132	136	140	144	148	152	156	161	166	171	176	181	186
21	118	120	123	126	130	134	138	141	145	149	153	157	162	167	172	177	182	187
22	119	121	124	127	131	135	139	142	146	150	154	158	163	168	173	178	183	188
23	120	122	125	128	132	136	140	143	147	151	155	159	164	169	175	180	185	190
24	121	123	126	129	133	137	141	144	148	152	156	160	165	171	177	182	187	192
25	122	124	126	129	133	137	141	145	149	153	157	162	167	173	179	184	189	194
26	123	125	127	130	134	138	142	146	150	154	158	163	168	174	180	186	191	196
27	124	126	128	131	134	138	142	146	150	154	158	163	169	175	181	187	192	197
28	125	127	129	132	135	139	143	147	151	155	159	164	170	176	182	188	193	198
29	126	128	130	133	136	140	144	148	152	156	160	165	171	177	183	189	194	199
30	126	128	130	133	136	140	144	148	152	156	161	166	172	178	184	190	196	201
31	127	129	131	134	137	141	145	149	153	157	162	167	173	179	185	191	197	202
32	127	129	131	134	137	141	145	149	154	158	163	168	174	180	186	192	198	203
33	127	129	131	134	137	141	145	149	154	159	164	169	175	181	187	193	199	204
34	128	130	132	135	138	142	146	150	155	160	165	170	176	182	188	194	200	206
35	128	130	132	135	138	142	146	150	155	160	165	170	176	182	189	195	201	207
36	129	131	133	136	139	143	147	151	156	161	166	171	177	183	190	196	202	208
37	129	131	133	136	140	144	148	152	157	162	167	172	178	184	191	197	203	209
38	130	132	134	137	140	144	148	152	157	162	167	173	179	185	192	198	204	210
39	130	132	134	137	140	144	148	152	157	162	167	173	179	185	192	199	205	211
40	131	133	135	138	141	145	149	153	158	163	168	174	180	186	193	200	206	212
41	131	133	135	138	141	145	149	153	158	163	168	174	180	186	193	200	207	213
42	132	134	136	139	142	146	150	154	159	164	169	175	181	187	194	201	208	214
43	132	134	136	139	142	146	150	154	159	164	169	175	181	187	194	201	208	214
44	133	135	137	140	143	147	151	155	160	165	170	176	182	188	195	202	209	215

TABLE 8—*Continued*

AGE	5 FEET	5 FEET 1 INCH	5 FEET 2 INCHES	5 FEET 3 INCHES	5 FEET 4 INCHES	5 FEET 5 INCHES	5 FEET 6 INCHES	5 FEET 7 INCHES	5 FEET 8 INCHES	5 FEET 9 INCHES	5 FEET 10 INCHES	5 FEET 11 INCHES	6 FEET	6 FEET 1 INCH	6 FEET 2 INCHES	6 FEET 3 INCHES	6 FEET 4 INCHES	6 FEET 5 INCHES
45	133	135	137	140	143	147	151	155	160	165	170	176	182	188	195	202	209	215
46	134	136	138	141	144	148	152	156	161	166	171	177	183	189	196	203	210	216
47	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
48	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
49	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
50	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
51	135	137	139	142	145	149	153	157	162	167	172	178	184	191	198	205	212	218
52	135	137	139	142	145	149	153	157	162	167	172	178	184	191	198	205	212	218
53	135	137	139	142	145	149	153	157	162	167	172	178	184	191	198	205	212	218
54	135	137	139	142	145	149	153	158	163	168	173	178	184	191	198	205	212	219
55 and up	135	137	139	142	145	149	153	158	163	168	173	178	184	191	198	205	212	219

some individuals will be overweight, while others will be underweight according to these tables. In recent years, Dreyer, Gray, Parmenter and others have stated that there is a close correlation between body weight and such measurements as sitting height and chest circumference. Until further research has been made on this subject, however, one is justified in using the life insurance tables.

Surface area. Peabody and Wentworth, West, Dreyer and others have reported a very close correlation existing between the vital capacity of the lungs and the surface area of the body. The work of Du Bois and Du Bois is accepted generally as proposing our present most accurate method of arriving at the surface area of the body. From the surface area formula of these authors a very convenient graphic chart has been made by Boothby and Sandiford (fig. 30). From this chart one may obtain the body surface area of an individual when only weight and standing height are known. No mathematical calculations are necessary.

TABLE 9

Standard weight according to height and age—women

After Association of Life Insurance Medical Directors and the Actuarial Society of America

AGE	4 FEET 8 INCHES	4 FEET 9 INCHES	4 FEET 10 INCHES	4 FEET 11 INCHES	5 FEET	5 FEET 1 INCH	5 FEET 2 INCHES	5 FEET 3 INCHES	5 FEET 4 INCHES	5 FEET 5 INCHES	5 FEET 6 INCHES	5 FEET 7 INCHES	5 FEET 8 INCHES	5 FEET 9 INCHES	5 FEET 10 INCHES	5 FEET 11 INCHES	6 FEET
15	101	103	105	106	107	109	112	115	118	122	126	130	134	138	142	147	152
16	102	104	106	108	109	111	114	117	120	124	128	132	136	139	143	148	153
17	103	105	107	109	111	113	116	119	122	125	129	133	137	140	144	149	154
18	104	106	108	110	112	114	117	120	123	126	130	134	138	141	145	150	155
19	105	107	109	111	113	115	118	121	124	127	131	135	139	142	146	151	155
20	106	108	110	112	114	116	119	122	125	128	132	136	140	143	147	151	156
21	107	109	111	113	115	117	120	123	126	129	133	137	141	144	148	152	156
22	107	109	111	113	115	117	120	123	126	129	133	137	141	145	149	153	157
23	108	110	112	114	116	118	121	124	127	130	134	138	142	146	150	153	157
24	109	111	113	115	117	119	121	124	127	130	134	138	142	146	150	154	158
25	109	111	113	115	117	119	121	124	128	131	135	139	143	147	151	154	158
26	110	112	114	116	118	120	122	125	128	131	135	139	143	147	151	155	159
27	110	112	114	116	118	120	122	125	129	132	136	140	144	148	152	155	159
28	111	113	115	117	119	121	123	126	130	133	137	141	145	149	153	156	160
29	111	113	115	117	119	121	123	126	130	133	137	141	145	149	153	156	160
30	112	114	116	118	120	122	124	127	131	134	138	142	146	150	154	157	161
31	113	115	117	119	121	123	125	128	132	135	139	143	147	151	154	157	161
32	113	115	117	119	121	123	125	128	132	136	140	144	148	152	155	158	162
33	114	116	118	120	122	124	126	129	133	137	141	145	149	153	156	159	162
34	115	117	119	121	123	125	127	130	134	138	142	146	150	154	157	160	163
35	115	117	119	121	123	125	127	130	134	138	142	146	150	154	157	160	163
36	116	118	120	122	124	126	128	131	135	139	143	147	151	155	158	161	164
37	116	118	120	122	124	126	129	132	136	140	144	148	152	156	159	162	165
38	117	119	121	123	125	127	130	133	137	141	145	149	153	157	160	163	166
39	118	120	122	124	126	128	131	134	138	142	146	150	154	158	161	164	167
40	119	121	123	125	127	129	132	135	138	142	146	150	154	158	161	164	167
41	120	122	124	126	128	130	133	136	139	143	147	151	155	159	162	165	168
42	120	122	124	126	128	130	133	136	139	143	147	151	155	159	162	166	169
43	121	123	125	127	129	131	134	137	140	144	148	152	156	160	163	167	170
44	122	124	126	128	130	132	135	138	141	145	149	153	157	161	164	168	171

TABLE 9—*Continued*

AGE	4 FEET 8 INCHES	4 FEET 9 INCHES	4 FEET 10 INCHES	4 FEET 11 INCHES	5 FEET	5 FEET 1 INCH	5 FEET 2 INCHES	5 FEET 3 INCHES	5 FEET 4 INCHES	5 FEET 5 INCHES	5 FEET 6 INCHES	5 FEET 7 INCHES	5 FEET 8 INCHES	5 FEET 9 INCHES	5 FEET 10 INCHES	5 FEET 11 INCHES	6 FEET
45	122	124	126	128	130	132	135	138	141	145	149	153	157	161	164	168	171
46	123	125	127	129	131	133	136	139	142	146	150	154	158	162	165	169	172
47	123	125	127	129	131	133	136	139	142	146	151	155	159	163	166	170	173
48	124	126	128	130	132	134	137	140	143	147	152	156	160	164	167	171	174
49	124	126	128	130	132	134	137	140	143	147	152	156	161	165	168	172	175
50	125	127	129	131	133	135	138	141	144	148	152	156	161	165	169	173	176
51	125	127	129	131	133	135	138	141	144	148	152	157	162	166	170	174	177
52	125	127	129	131	133	135	138	141	144	148	152	157	162	166	170	174	177
53	125	127	129	131	133	135	138	141	144	148	152	157	162	166	170	174	177
54	125	127	129	131	133	135	138	141	141	144	153	158	163	167	171	174	177
55 and up	125	127	129	131	133	135	138	141	144	148	153	158	163	167	171	174	177

Sitting height (*stem length*). A special device, such as that described by Dreyer, is desirable for taking this measurement. The subject sits on a low platform with the sacrum pressed firmly against a perpendicular bar. If such a measuring device is not available the subject may sit on the floor with the sacrum firmly pressed against a door-casing. With a small perpendicular bar bearing a scale and a small horizontal bar the distance is measured from the floor to the top of the head. Dreyer has shown that the position described above gives most accurate results. Any other position, such as in sitting on a chair, introduces considerable error because of the gluteal muscles.

Chest circumference. This measurement is usually taken at the level of the fourth interspace. Dreyer prefers to take the reading when the subject is breathing quietly, while Gray believes a more accurate reading may be obtained by using the average of the circumferences taken on forced

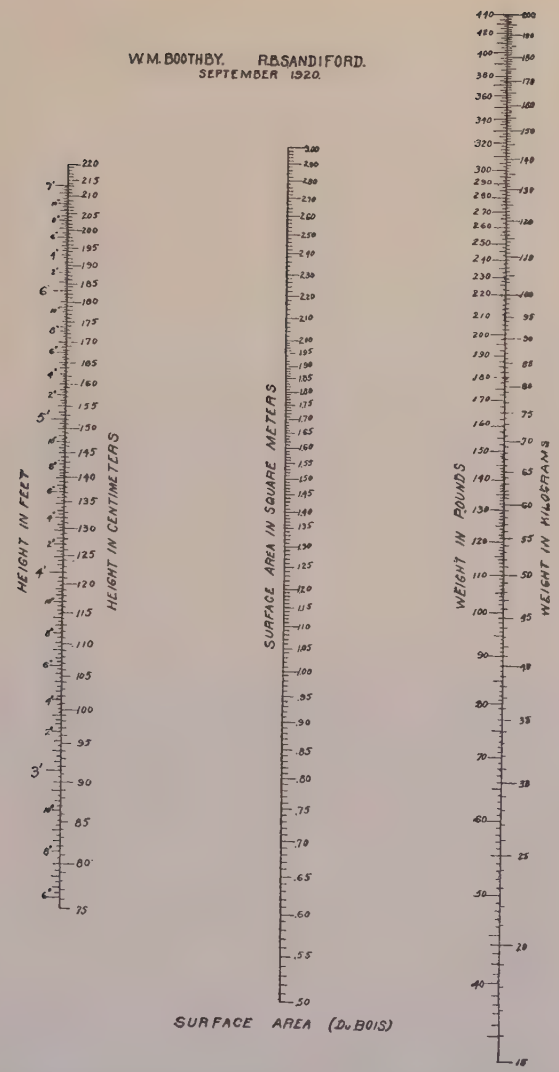

FIG. 30. QUICK AND ACCURATE METHOD OF DETERMINING THE SURFACE AREA OF THE BODY

"In order to determine the surface area, place the needle on the scale representing the weight of the subject (53.1 kgm.); bring the ruler against the needle and swing its other end exactly over the height of the subject (155 cm.) and read the answer (1.50 sq.m.) on the middle scale." (After Boothby and Sandiford.)

inspiration and forced expiration. Dreyer has shown that the chest circumference taken over the mammary glands of the female is 4.5 per cent greater than that taken just below the glands; therefore, he recommends the latter method of measurement. Parmenter and Gray have stated that the chest circumference taken at the level of the xiphoid process is as closely correlated with weight as when taken at the nipple level. Moreover, being a bony point, it is less subject to changes from emaciation and obesity. From our present knowledge it seems preferable to take the chest circumference at the level of the xiphoid process and to use the average of the circumferences taken on forced inspiration and forced expiration.

Record of measurements. Before proceeding further, one should make a permanent record of the measurement necessary in each individual case, inasmuch as comparisons with subsequent measurements may prove very helpful in certain cases. Such a suggested record follows:

Name: J. B. C. Date: August 1, 1924 Age: 30 years

Occupation: Farmer.	Past actual body weight while in good health:
Vital capacity: 4300 cc.	
Standing height: 165 cm.	Surface area: 170 sq. m.
Present body weight: 65 kgm.	Sitting height: 90 cm.
Theoretical normal body weight:	Chest circumference: 86 cm.

CHAPTER VI

Normal Vital Capacity Standards

It is obvious that before any test can render its greatest service, reasonably accurate normal standards must be developed for comparative purposes. Because of wide individual variations, we know that individual standards observed in time of good health are best but inasmuch as such standards are not available in most cases one is compelled to resort to theoretical normal standards. Since Hutchinson began his work upon vital lung capacity several theoretical normal standards have been presented, such as the standing height standard, the body weight standard, the surface area standard, the sitting height standard and the chest circumference standard. We shall consider briefly the development of some of these more important normal standards and their relative value in the light of present day investigations.

Standing height standard. In his pioneer work on vital lung capacity Hutchinson found the standing height standard the most important. Since Hutchinson's report, Fabius, Wintrich, Cornet, Peabody and Wentworth, and others have thought the standing height standards of value. On the other hand, Dreyer believed that there is no close correlation between the vital capacity of the lungs and the standing height of the individual. Hutchinson stated that "for every inch of height (from 5 to 6 feet) 8 additional cubic inches of air, at 60°, are given out by a forced expiration." After a careful biometric study of the inter-relations of vital capacity and certain other measurements of

TABLE 10

PERCENTAGE OF VITAL CAPACITY - MEN (CALCULATED FROM STANDING HEIGHT)

Standing Height in Inches	Vital Capacity in Cubic Centimeters																									
	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200
57	19	22	25	28	30	33	36	39	41	44	47	50	52	55	58	61	64	66	69	72	75	77	80	83	86	88
58	19	22	24	27	30	33	35	38	41	43	46	49	52	54	57	60	63	65	68	71	73	76	79	82	84	87
59		21	24	27	29	32	35	37	40	43	45	48	51	53	56	59	61	64	67	69	72	75	77	80	83	85
60		21	24	26	29	32	34	37	39	42	45	47	50	53	55	58	60	63	66	68	71	74	76	79	81	84
61		21	23	26	28	31	34	36	39	41	44	47	49	52	54	57	59	62	65	67	70	72	75	78	80	83
62		20	23	25	28	30	33	36	38	41	43	46	48	51	53	56	58	61	64	66	69	71	74	76	79	81
63		20	23	25	28	30	33	35	38	40	43	45	48	50	53	55	58	60	63	65	68	70	73	75	78	80
64		20	22	25	27	30	32	35	37	39	42	44	47	49	52	54	57	59	62	64	67	69	71	74	76	79
65			22	24	27	29	32	34	36	39	41	44	46	48	51	53	56	58	61	63	66	68	70	73	75	78
66			21	24	26	29	31	33	36	38	41	43	45	48	50	52	55	57	60	62	64	67	69	71	74	76
67			21	24	26	28	31	33	35	38	40	42	45	47	49	52	54	56	59	61	63	66	68	71	73	75
68			21	23	26	28	30	32	35	37	39	42	44	46	49	51	53	56	58	60	63	65	67	70	72	74
69			21	23	25	27	30	32	34	37	39	41	43	46	48	50	52	55	57	59	62	64	66	68	71	73
70			20	22	25	27	29	31	34	36	38	40	43	45	47	49	52	54	56	58	61	63	65	67	70	72
71			20	22	24	27	29	31	33	35	38	40	42	44	47	49	51	53	55	58	60	62	64	67	69	71
72			20	22	24	26	28	31	33	35	37	39	42	44	46	48	50	53	55	57	59	61	63	66	68	70
73			19	22	24	26	28	30	32	35	37	39	41	43	45	47	50	52	54	56	58	60	63	65	67	69
74			19	21	23	26	28	30	32	34	36	38	40	43	45	47	49	51	53	55	57	60	62	64	66	68
75				21	23	25	27	29	32	34	36	38	40	42	44	46	48	50	53	55	57	59	61	63	65	67
76				21	23	25	27	29	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66
Vital Capacity in Cubic Inches	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2

Standing Height in Inches	Vital Capacity in Cubic Centimeters																										Standing Height in cm.
	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	
57	91	94	97	99	102	105	108	110	113	116	119	121															144.8
58	90	92	95	98	100	103	106	109	111	114	117	120	122														147.3
59	88	91	93	96	99	101	104	107	109	112	115	117	120	123													149.8
60	87	89	92	95	97	100	102	105	108	110	113	115	118	121	123												152.4
61	85	88	90	93	96	98	101	103	106	108	111	114	116	119	121	124											154.9
62	84	86	89	91	94	97	99	102	104	107	109	112	114	117	119	122											157.4
63	83	85	88	90	93	95	98	100	103	105	108	110	113	115	118	120	123										160.0
64	81	84	86	89	91	94	96	99	101	103	106	108	111	113	116	118	120	123									162.5
65	80	82	85	87	90	92	95	97	99	102	104	107	109	111	114	116	119	121	123								165.1
66	79	81	83	86	88	91	93	95	98	100	102	105	107	110	112	114	117	119	121	124							167.6
67	78	80	82	85	87	89	92	94	97	99	101	104	106	108	111	113	115	118	120	122							170.2
68	76	79	81	83	86	88	90	93	95	97	100	102	104	107	109	111	114	116	118	120	123						172.7
69	75	78	80	82	84	87	89	91	94	96	98	100	103	105	107	109	112	114	116	119	121	123					175.3
70	74	76	79	81	83	86	88	90	92	94	97	99	101	103	106	108	110	112	115	117	119	121	124				177.8
71	73	75	78	80	82	84	86	89	91	93	95	98	100	102	104	106	109	111	113	115	117	120	122	124			180.4
72	72	74	77	79	81	83	85	88	90	92	94	96	98	101	103	105	107	109	111	114	116	118	120	122	125		182.9
73	71	73	76	78	80	82	84	86	89	91	93	95	97	99	101	103	106	108	110	112	114	117	119	121	123		185.4
74	70	72	75	77	79	81	83	85	87	89	92	94	96	98	100	102	104	106	108	111	113	115	117	119	121	123	188.0
75	69	71	73	76	78	80	82	84	86	88	90	92	95	97	99	101	103	105	107	109	111	113	116	118	120	122	190.5
76	68	70	72	75	77	79	81	83	85	87	89	91	93	95	97	99	101	104	106	108	110	112	114	116	118	120	193.0
Vital Capacity in Cubic Inches	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	298.9	305.0	311.1	317.2	323.3	329.4	335.5	341.6	347.7	353.8	

Take the standing height of the patient, either in inches or centimeters. Locate in the vertical column, at the extreme left or extreme right of the table, the figure which corresponds most closely to the standing height. Take the patient's vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom of the table the figure which corresponds most closely to the vital capacity observed. Now follow the vertical column from the figure representing the vital capacity to the place where it intersects the horizontal column leading from the figure representing the height. In the square where the two columns intersect will be found the percentage of the theoretical normal vital capacity of the patient. If the height observed falls between the height figures on the table, one may easily calculate the percentage. Calculation may be made in a similar manner when the vital capacity observed falls between the vital capacity figures on the table. (After Myers.)

TABLE 11

Percentage of Vital Capacity-Women (Calculated from Standing Height)

Standing Height in Inches	Vital Capacity in Cubic Centimeters																																								Standing Height in cm.
	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	
55	21	25	29	32	36	39	43	47	50	54	57	61	64	68	71	75	79	82	86	89	93	96	100	103	107	111	114	118	121												139.7
56	21	25	28	32	35	39	42	46	49	53	56	60	63	67	70	74	77	81	84	88	91	95	98	102	105	109	112	116	119	123											142.2
57	21	24	28	31	35	38	41	45	48	52	55	59	62	66	69	72	76	79	83	86	90	93	97	100	103	107	110	114	117	121											144.8
58	20	24	27	31	34	38	41	44	47	51	54	58	61	64	68	71	75	78	81	85	88	91	95	98	102	105	108	112	115	118	122										147.3
59	20	23	27	30	33	37	40	43	47	50	53	57	60	63	67	70	73	77	80	83	87	90	93	97	100	103	107	110	113	117	120	123									149.8
60	20	23	26	30	33	36	39	43	46	49	52	56	59	62	66	69	72	75	79	82	85	88	92	95	98	102	105	108	112	115	118	121									152.4
61		23	26	29	32	36	39	42	45	48	52	55	58	61	65	68	71	74	77	81	84	87	90	94	97	100	103	106	110	113	116	119	122								154.9
62		22	25	29	32	35	38	41	44	48	51	54	57	60	63	67	70	73	76	79	83	86	89	92	95	98	102	105	108	111	114	118	121								157.4
63		22	25	28	31	35	38	41	44	47	50	53	56	59	62	66	69	72	75	78	81	84	88	91	94	97	100	103	106	109	112	116	119	122							160.0
64		22	25	28	31	34	37	40	43	46	49	52	55	58	62	65	68	71	74	77	80	83	86	89	92	95	98	101	105	108	111	114	117	120							162.5
65		21	24	27	30	33	36	39	42	46	49	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115	118	121						165.1
66		21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	98	101	104	107	110	113	116	119	122					167.6
67		21	24	27	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	79	82	85	88	91	94	97	100	103	106	109	112	115	118	120	123				170.2
68		20	23	26	29	32	35	38	41	44	46	49	52	55	58	61	64	67	69	72	75	78	81	84	87	90	93	96	98	101	104	107	110	113	116	119	121				172.7
69		20	23	26	29	31	34	37	40	43	46	49	51	54	57	60	63	66	68	71	74	77	80	83	85	88	91	94	97	100	102	105	108	111	114	117	120	123			175.3
70		20	22	25	28	31	34	37	39	42	45	48	51	53	56	59	62	65	67	70	73	76	79	82	84	87	90	93	96	98	101	104	107	110	112	115	118	121			177.8
71			22	25	28	31	33	36	39	42	44	47	50	53	55	58	61	64	66	69	72	75	78	80	83	86	89	91	94	97	100	102	105	108	111	114	116	119	122		180.4
72			22	25	27	30	33	36	38	41	44	47	49	52	55	57	60	63	66	68	71	74	77	79	82	85	88	90	93	96	98	101	104	107	109	112	115	118	120		182.9
73			22	24	27	30	32	35	38	40	43	46	49	51	54	57	59	62	65	67	70	73	76	78	81	84	86	89	92	94	97	100	102	105	108	111	113	116	119	121	185.4
74			21	24	27	29	32	35	37	40	43	45	48	51	53	56	59	61	64	67	69	72	75	77	80	83	85	88	90	93	96	99	101	104	106	109	112	114	117	120	188.0
	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	
	Vital Capacity in Cubic Inches																																								

This table is used in the same manner as table 10. (After Myers)

the body, Cripps, Greenwood, and Newbold concluded that an increase of one inch in standing height gives an increase of 8.88 inches in vital capacity. Furthermore they stated that "The substitution of stem length for height does not improve the accuracy of prediction, and with the minor

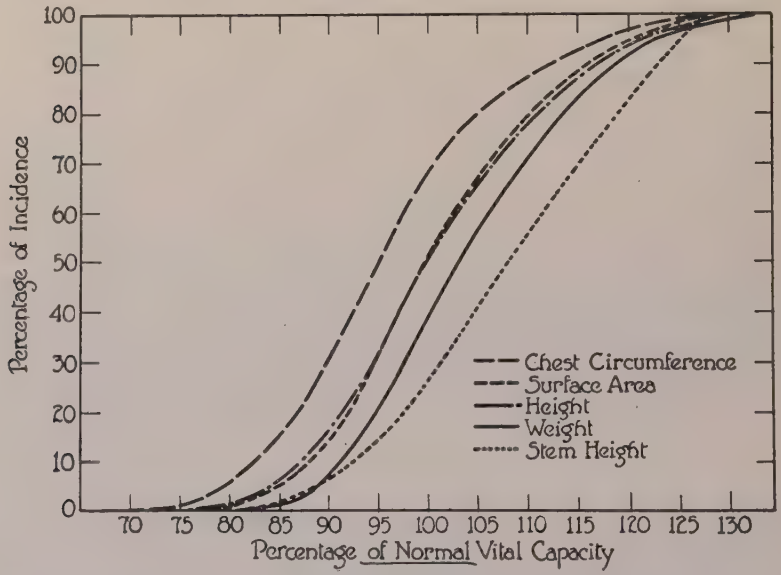

FIG. 31. CURVES DRAWN TO SHOW THE RESULTS OBTAINED IN VITAL CAPACITY WORK BY THE USE OF VARIOUS STANDARDS

The data for these curves were obtained from observations on 1641 normal male University students. Note the close relationship between the curves representing the surface area, the height and the weight standards. (After Shepard and Myers.)

exceptions noticed above, Hutchinson's method is as good or better than its recent modifications." Rogers recently found the standing height standard quite satisfactory. West has concluded that "For quick clinical work, where it is not practicable to obtain the net weight of the patient nor to make extensive measurements, a simple comparison between the vital capacity and the height will give a value

which will closely approximate the normal for that individual, though individual variations by that method are greater than when the surface area is used." West found that for every centimeter in height a man gains 25 cc. of air while a woman gains only 20 cc. Bowen and Platt and others have found these ratios quite satisfactory.

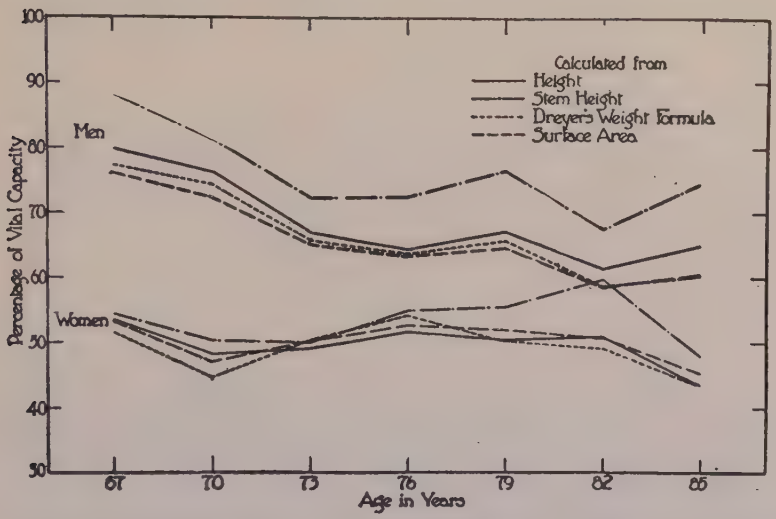

FIG. 32. CURVES DRAWN TO SHOW THE EFFECTS OF SENILITY UPON THE VITAL CAPACITY

Note how closely the relationship between the curves representing the surface area, the height and the weight standards persist into and through senility. (After Myers and Cady.)

After a careful study of 400 college students, Hewlett and Jackson concluded that "Among college students the correlation of vital capacity with a combination of weight and height is a little better than the correlation with either separately."

Tables 10 and 12 were prepared from the ratios given by West, Boynton, Shepard, Maeder, Cady and Myers have applied these tables to good-sized groups of normal men and

women and have obtained reasonably satisfactory results (figs. 31 and 32). One advantage in using the standing height standard is that it is not affected by obesity of the subject. For children Edwards and Wilson say "The correlation between vital capacity and body height is more intimate than that between vital capacity and surface area or body weight." They found an average of 15.5 cc. of vital capacity for each centimeter of standing height. (For standing height standards for children, see tables 20 and 21.)

Surface area standard. In 1917 Peabody and Wentworth conceived the idea that a close correlation exists between the vital capacity of the lungs and the surface area of the body. They made a few observations which proved satisfactory, whereupon they suggested that a study be made upon a larger number of individuals. West took up this problem and in 1920 published his results. In this work West made a comparison of the various standards for determining the normal vital capacity and concluded that "A standard based on the body surface area is advised, since it has been shown that the vital capacity varies with this function more uniformly than with others tried." For obtaining the body surface area, West used the graphic chart of DuBois and DuBois. He found that for each square meter of body surface men have a vital capacity of 2.5 liters while women have a vital capacity of only 2 liters. At the present time this method of West's is becoming quite generally adopted because it is easy to use and apparently is as accurate as any method in use. In a group of 94 nurses Myers found this ratio to be 1.87 liters per square meter of body surface. The same figure was obtained by Lemon and Moersch from a study of 166

TABLE 12

PERCENTAGE OF VITAL CAPACITY - MEN (CALCULATED FROM SURFACE AREA)

Vital Capacity in Cubic Centimeters

Surface Area in Sq. M.	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	Surface Area in Sq. M.
.7	34	40	46	51	57	63	69	74	80	86	92	97	103	108	114	120	125																																						.7
.75	32	37	43	48	53	59	64	69	75	80	85	91	96	101	107	112	117	123																																					.75
.8	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125																																			.8
.85	28	33	38	42	47	52	57	61	66	71	75	80	85	90	94	99	104	107	113	118	122																																		.85
.9	27	31	35	40	44	49	53	58	62	67	71	76	80	85	89	93	98	102	107	111	115	120																																	.9
.95	25	29	34	38	42	46	51	55	59	63	67	72	76	80	84	88	93	97	101	105	109	114	118	122																															.95
1.0	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120																														1.0
1.05	23	27	30	34	38	42	46	50	53	57	61	65	69	72	76	80	84	88	91	95	99	103	107	110	114	118	122																												1.05
1.1	22	25	29	33	36	40	44	47	51	55	58	62	65	69	73	76	80	84	87	91	95	98	102	105	109	113	116	120	123																										1.1
1.15	21	24	28	31	35	38	42	45	49	52	56	59	63	66	70	73	77	80	84	87	91	94	98	101	104	108	111	115	118	122																									1.15
1.2	20	23	27	30	33	37	40	43	47	50	53	57	60	64	69	70	73	77	80	83	87	90	93	97	100	103	107	110	113	117	120																								1.2
1.25		22	26	29	32	35	38	42	45	48	51	54	58	61	64	67	70	74	77	80	83	86	90	93	96	99	102	106	109	112	115	118	122																						1.25
1.3		22	25	28	31	34	37	40	43	46	49	52	55	59	62	65	68	71	74	77	80	83	86	89	92	95	99	101	105	118	111	114	117	120																					1.3
1.35		21	24	27	30	33	36	39	42	44	47	50	53	56	59	62	65	68	71	74	77	80	83	86	89	92	95	98	101	114	107	110	113	115	118	121																			1.35
1.4		20	23	26	29	31	34	37	40	43	46	49	51	54	57	60	63	66	69	72	74	77	80	83	86	89	91	94	97	100	103	106	109	111	114	117	120																		1.4
1.45			22	25	28	30	33	36	39	41	44	47	50	52	55	58	61	64	66	69	72	75	77	80	83	86	88	91	94	97	99	102	105	108	110	113	116	119	121																1.45
1.5			21	24	27	29	32	35	37	40	43	45	48	51	53	56	59	61	64	67	69	72	75	77	80	83	85	88	91	93	96	99	101	104	107	109	112	115	117	120															1.5
1.55			20	23	26	28	31	34	36	39	41	44	46	49	52	54	57	59	62	65	67	70	72	75	77	80	83	85	88	90	93	96	98	101	103	106	108	111	114	116	119	121													1.55
1.6			20	22	25	28	30	33	35	38	40	43	45	48	50	53	55	58	60	63	65	68	70	73	75	78	80	83	85	88	90	93	95	98	100	103	105	108	110	113	115	118	120												1.6
1.65				22	24	27	29	32	34	36	39	41	44	46	49	51	53	56	58	61	63	66	68	70	73	75	78	80	82	85	87	90	92	94	97	99	102	104	107	109	111	114	116	119	121										1.65
1.7				21	24	26	28	31	33	35	38	40	43	45	47	50	52	54	57	59	61	64	66	68	71	73	75	78	80	82	85	87	89	92	94	96	99	101	103	106	108	110	113	115	117	120									1.7
1.75				21	23	25	27	30	32	34	37	39	41	43	46	48	50	53	55	57	60	62	64	66	69	71	73	75	78	80	82	85	87	89	91	94	96	98	101	103	105	107	110	112	114	117	119	121							1.75
1.8				20	22	24	27	29	31	33	36	38	40	42	44	47	49	51	53	56	58	60	62	65	67	69	71	73	76	78	80	82	85	87	89	91	93	96	98	100	102	104	107	109	111	113	115	118	120						1.8
1.85					22	24	26	28	30	32	35	37	39	41	43	45	48	50	52	54	56	58	61	63	65	67	69	71	74	76	78	80	82	84	87	89	91	93	95	97	99	102	104	106	108	110	112	114	117	119	121				1.85
1.9					21	23	25	27	30	32	34	36	38	40	42	44	46	48	51	53	55	57	59	61	63	65	68	69	72	74	76	78	80	82	84	86	88	91	93	95	97	99	101	103	105	107	109	112	114	116	118	120			1.9
1.95					20	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	97	98	100	103	105	107	109	111	113	115	117	119	121	1.95
2.0					20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	2.0
2.05						22	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	101	103	105	107	109	111	113	115	2.05
2.1						21	23	25	27	29	31	32	34	36	38	40	42	44	46	48	50	51	53	55	57	59	61	63	65	67	69	71	72	74	76	78	80	82	84	86	88	90	91	93	95	97	99	101	103	105	107	108	110	112	2.1
2.15						21	22	24	26	28	30	32	34	35	37	39	41	43	45	47	48	50	52	54	56	58	50	61	63	65	67	69	71	73	74	76	78	80	82	84	86	87	89	91	93	95	97	99	100	102	104	106	108	110	2.15
2.2						20	22	24	25	27	29	31	33	35	36	38	40	42	44	46	47	49	51	53	55	56	58	60	62	64	66	67	69	71	73	74	76	78	80	82	84	85	87	89	91	93	95	96	98	100	102	104	105	107	2.2
2.25							21	23	25	27	28	30	32	34	36	37	39	41	43	45	46	48	50	52	54	55	57	59	60	62	64	66	68	69	71	73	75	76	78	80	82	84	85	87	89	91	93	94	96	98	100	101	103	105	2.25
2.3							21	23	24	26	28	30	31	33	35	37	38	40	42	44	45	47	49	50	52	54	56	57	59	61	63	64	66	68	70	71	73	75	77	78	80	82	84	85	87	89	90	92	94	96	97	99	101	103	2.3
2.35							20	22	24	26	27	29	31	32	34	36	37	39	41	43	44	46	48	49	51	53	54	56	58	60	61	63	65	66	68	70	71	73	75	77	78	80	82	83	85	87	89	90	92	94	95	97	99	100	2.35
2.4							20	22	23	25	27	28	30	32	33	35	37	38	40	42	43	45	47	48	50	52	53	55	57	58	60	62	63	65	67	68	70	72	73	75	77	78	80	82	83	85	87	88	90	92	93	95	97	98	2.4
2.45								21	23	25	26	28	29	31	33	34	36	38	39	41	42	44	46	47	49	51	52	54	56	57	59	60	62	64	65	67	69	70	72	73	75	77	78	80	82	83	85	87	88	90	92	93	95	96	2.45
2.5								21	22	24	26	27	29	30	32	34	35	37	38	40	42	43	45	46	48	50	51	53	54	56	58	59	61	62	64	66	67	69	70	72	74	75	77	78	80	82	83	85	86	88	90	91	93	94	2.5
	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	298.9	305.0	311.1	317.2	323.3	329.4	335.5	341.6	347.7	353.8	359.9	

Vital Capacity in Cubic Inches

Locate in the vertical column at the extreme left or extreme right the figure which corresponds most closely with the surface area of the patient. Take the patient's vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom of the table the figure which corresponds most closely to the vital capacity observed. Now use the table in precisely the same manner as table 10 is used.

women. In constructing table 12, West's ratio of 2.5 liters of air to 1 square meter of body surface was used. Owing to the fact, however, that Lemon and Moersch and Myers found a somewhat smaller vital capacity per square meter of surface area than West reported in women the

TABLE 13

PERCENTAGE OF VITAL CAPACITY – WOMEN (CALCULATED FROM SURFACE AREA)

Surface Area in Sq. M.	Vital Capacity in Cubic Centimeters 400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800
.5	42	52	63	73	84	94	104	115	125						
.55	38	47	57	66	76	85	95	104	114	123					
.6	35	43	52	61	69	78	87	95	104	113	122				
.65	32	40	48	56	64	72	80	88	96	104	112	120			
.7	30	37	45	52	60	67	75	82	90	97	104	112	119	127	
.75	28	35	42	49	56	63	69	76	83	90	97	104	111	118	125
.8	26	33	39	46	52	59	66	72	78	85	91	98	104	111	117
.85	25	31	37	43	49	55	61	67	74	80	86	92	98	104	110
.9	23	29	35	40	46	52	58	64	69	75	81	87	93	98	104
.95	22	27	33	38	44	49	55	60	66	71	77	82	88	93	99
1.0	21	26	31	37	42	47	52	57	63	68	73	78	83	89	94
1.05	20	25	30	35	40	45	50	55	60	64	69	74	79	84	89
1.1		24	28	33	38	43	47	52	57	62	66	71	76	80	85
1.15		23	27	32	36	41	45	50	54	59	63	68	72	77	81
1.2		22	26	30	35	39	43	48	52	56	61	65	69	74	78
1.25		21	25	29	33	37	42	46	50	54	58	63	67	71	75
1.3		20	24	28	32	36	40	44	48	52	56	60	64	68	72
1.35			23	27	31	35	39	42	46	50	54	58	62	66	70
1.4			22	26	30	33	37	41	45	48	52	56	60	63	67
1.45			22	25	29	32	36	40	43	47	50	54	57	61	65
1.5			21	24	28	31	35	38	42	45	49	52	56	59	63
1.55			20	23	27	30	34	37	40	44	47	50	54	57	60
1.6			20	23	26	29	33	36	39	42	46	49	52	55	59
1.65				22	25	28	32	35	38	41	44	47	51	54	57
1.7				21	25	28	31	34	37	40	43	46	49	52	55
1.75				21	24	27	30	33	36	39	42	45	48	51	54
1.8				20	23	26	29	32	35	38	40	43	46	49	52
1.85				20	23	25	28	31	34	37	40	42	45	48	51
1.9					22	25	27	30	33	36	38	41	44	47	49
1.95					21	24	27	29	32	35	37	40	43	45	48
2.0					21	23	26	29	31	34	36	39	42	44	47
2.05					20	23	25	28	31	33	36	38	41	43	46
2.1					20	22	25	27	30	32	35	37	40	42	45
2.15						22	24	26	29	31	34	36	39	41	44
2.2						21	24	26	28	31	33	36	38	40	43
2.25						21	23	25	28	30	32	35	37	39	42
2.3						20	23	25	27	29	32	34	36	39	41
2.35						20	22	24	27	29	31	33	35	38	40
2.4						20	22	24	26	28	30	33	35	37	39
Vital Capacity in Cubic Inches	24.4	30.5	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8

Surface Area in Sq. M.	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300
.5															
.55															
.6															
.65															
.7															
.75															
.8	124														
.85	116	123													
.9	110	116	122												
.95	104	110	115	121	126										
1.0	99	104	109	115	120	125									
1.05	94	99	104	109	114	119	124								
1.1	90	95	99	104	109	113	118	123							
1.15	86	91	95	100	104	109	113	118	122						
1.2	83	87	91	96	100	104	108	113	117	122					
1.25	79	83	88	92	96	100	104	108	113	117	121				
1.3	76	80	84	88	92	96	100	104	108	112	116	120	124		
1.35	73	77	81	85	89	93	97	100	104	107	112	116	120	123	
1.4	71	74	78	82	86	89	93	97	100	104	108	112	115	119	123
1.45	68	72	75	79	83	86	90	93	97	101	104	108	111	115	118
1.5	66	69	73	76	80	83	87	90	94	97	101	104	108	111	114
1.55	64	67	70	74	77	81	84	87	91	94	97	101	104	107	111
1.6	62	65	68	72	75	78	81	85	88	91	95	98	101	104	107
1.65	60	63	66	69	73	76	79	82	85	88	92	95	98	101	104
1.7	58	61	64	67	70	74	77	80	83	86	89	92	95	98	101
1.75	57	60	63	66	68	71	74	77	80	83	86	89	92	95	98
1.8	55	58	61	64	66	69	72	75	78	81	84	87	90	93	95
1.85	54	56	59	62	65	68	70	73	76	79	82	84	87	90	93
1.9	52	55	58	60	63	66	69	71	74	77	80	82	85	88	90
1.95	51	53	56	59	61	64	67	69	72	75	77	80	83	85	88
2.0	50	52	55	57	60	63	65	68	70	73	76	78	81	83	86
2.05	48	51	53	56	58	61	64	66	69	71	74	77	79	81	84
2.1	47	50	52	55	57	60	62	65	67	70	72	75	77	79	82
2.15	46	48	51	53	56	58	61	63	65	68	70	73	75	77	80
2.2	45	47	50	52	54	57	59	62	64	66	69	71	73	76	78
2.25	44	46	49	51	53	56	58	60	63	65	67	70	72	74	76
2.3	43	45	48	50	52	54	57	59	61	63	66	68	70	73	75
2.35	42	44	47	49	51	53	55	58	60	62	64	67	69	71	73
2.4	41	43	46	48	50	52	54	56	59	61	63	65	67	70	72
Vital Capacity in Cubic Inches	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3

3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	Surface Area in Sq. M.
													.5
													.55
													.6
													.65
													.7
													.75
													.8
													.85
													.9
													.95
													1.0
													1.05
													1.1
													1.15
													1.2
													1.25
													1.3
													1.35
													1.4
122													1.45
118	121												1.5
114	117	121											1.55
111	114	117	120										1.6
107	110	113	117	120									1.65
104	107	110	113	117	120	123							1.7
101	104	106	110	113	116	119	122						1.75
98	101	104	107	110	113	115	118	121					1.8
96	99	101	104	107	110	113	115	118	121				1.85
93	96	99	101	104	107	110	112	115	118	121			1.9
91	93	96	99	101	104	107	109	112	115	117	120	123	1.95
89	91	94	96	99	102	104	107	109	112	114	117	120	2.0
86	89	91	94	96	99	102	104	107	109	112	114	117	2.05
84	87	89	92	94	97	99	102	104	107	109	112	114	2.1
82	85	87	90	92	95	97	99	102	104	106	109	111	2.15
80	83	85	88	90	92	95	97	99	102	104	106	109	2.2
79	81	84	86	88	90	93	95	97	100	102	104	106	2.25
77	79	81	84	86	88	91	93	95	97	100	102	104	2.3
75	78	80	82	84	87	89	91	93	95	98	100	102	2.35
74	76	78	80	83	85	87	89	91	93	95	98	100	2.4
207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	Vital Capacity in Cubic Inches

This table is used in the same manner as table 12

ratio of 1.92 liters of air per square meter of body surface was used in preparing table 13. This is nearly an average figure, based on the reports of West, Lemon and Moersch and Myers. Boynton and Myers and Myers have applied table 13 to good-sized groups of college women and find

TABLE 14

PERCENTAGE OF VITAL CAPACITY — ME.1 (CALCULATED FROM BODY-WEIGHT)

Vital Capacity in Cubic Centimeters

Body Weight in Pounds	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400
90	20	23	26	30	33	36	40	43	46	50	53	56	59	63	66	69	73	76	79	82	86	89	92	96	99	102	105	109	112
95	19	22	25	29	32	35	38	41	45	48	51	54	57	60	64	67	70	73	76	79	83	86	89	92	95	99	102	105	108
100	18	21	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	80	83	86	89	92	95	98	101	104
105	18	21	24	27	30	33	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	83	86	89	92	95	98	101
110		20	23	26	29	31	34	37	40	43	46	49	51	54	57	60	63	66	69	71	74	77	80	83	86	89	91	94	97
115		19	22	25	28	30	33	36	39	42	44	47	50	53	56	58	61	64	67	69	72	75	78	81	83	86	89	92	94
120		19	21	24	27	30	32	35	38	40	43	46	48	51	54	56	59	62	64	67	70	73	75	78	81	83	86	89	91
125			21	23	26	29	31	34	37	39	42	44	47	50	52	55	57	60	63	65	68	70	73	76	78	81	83	86	89
130			20	23	25	28	30	33	36	38	41	43	46	48	51	53	56	58	61	63	66	68	71	74	76	79	81	84	86
135			20	22	25	27	30	32	35	37	39	42	44	47	49	52	54	57	59	62	64	67	69	72	74	77	79	81	84
140			19	22	24	26	29	31	34	36	38	41	43	47	48	50	53	55	58	60	62	65	67	70	72	74	77	79	82
145			19	21	23	26	28	30	33	35	37	40	42	44	47	48	52	54	56	59	61	63	66	68	70	73	75	77	80
150				20	23	25	27	30	32	34	37	39	41	43	46	48	50	53	55	57	59	62	64	66	69	71	73	75	78
155				20	22	25	27	29	31	34	36	38	40	42	45	47	49	51	54	56	58	60	63	65	67	69	72	74	76
160					22	24	26	28	31	33	35	37	39	41	43	46	48	50	52	55	57	59	61	63	66	68	70	72	74
165					21	24	26	28	30	32	34	36	38	41	43	45	47	49	51	53	56	58	60	62	64	66	68	71	73
170					21	23	25	27	29	31	33	36	38	40	42	44	46	48	50	52	54	56	59	61	63	65	67	69	71
175					20	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	60	61	64	66	68	70
180					20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68
185					20	22	24	26	28	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67
190					19	21	23	25	27	29	31	33	35	37	39	41	42	44	46	48	50	52	54	56	58	60	62	64	67
195					19	21	23	25	26	28	30	32	34	36	38	40	42	44	45	47	49	51	53	55	57	59	61	62	64
200					19	20	22	24	26	28	30	32	33	35	37	39	41	43	45	46	48	50	52	54	56	57	59	61	63
205						20	22	24	26	27	29	31	33	35	37	38	40	42	44	46	48	49	51	53	55	57	59	60	62
210						20	22	23	25	27	29	31	32	34	36	38	39	41	43	45	47	48	50	52	54	56	58	59	61
215						19	21	23	25	26	28	30	32	33	35	37	39	41	42	44	46	48	49	51	53	55	56	58	60
220						19	21	23	24	26	28	29	31	33	35	36	38	40	42	43	45	47	49	50	52	54	56	57	59
225						19	20	22	24	26	27	29	31	32	34	36	38	39	41	43	44	46	48	49	51	53	55	56	58
Vital Capacity in Cubic Inches	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4

Body Weight in Pounds	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	6000	6100	6200	Body Weight in Kg.
90	115	119	122																										40.8
95	111	114	118	121																									43.1
100	107	110	113	116	119	122																							45.4
105	104	107	109	112	115	118	121																						47.6
110	100	103	106	109	111	114	117	120																					49.9
115	97	100	103	105	108	111	114	116	119	122																			52.2
120	94	97	99	102	105	107	110	113	115	118	121																		54.4
125	91	94	97	99	102	104	107	110	112	115	117	120																	56.7
130	89	91	94	96	99	101	104	106	109	112	114	117	119	122															59.0
135	86	89	91	94	96	99	101	104	106	109	111	113	116	118	121														61.3
140	84	86	89	91	94	96	98	101	103	106	108	110	113	115	118	120	122												63.5
145	82	84	87	89	91	94	96	98	101	103	105	108	110	112	115	117	119	122											65.7
150	80	82	85	87	89	91	94	96	98	100	103	105	107	110	112	114	117	119	121										68.0
155	78	80	83	85	87	89	92	94	96	98	101	103	105	107	109	112	114	116	118	121									70.4
160	76	79	81	83	85	87	90	92	94	96	98	100	103	105	107	109	111	113	115	118	120								72.5
165	75	77	79	81	83	86	88	90	92	94	96	98	100	102	105	107	109	111	113	115	118	120							74.8
170	73	75	77	80	82	84	86	88	90	92	94	96	98	100	102	104	107	109	111	113	115	117	119	121					77.1
175	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	113	115	117	119	121				79.4
180	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120			81.6
185	69	71	73	75	77	79	81	83	85	87	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120		83.9
190	69	69	71	73	75	77	79	81	83	85	87	89	91	93	94	96	98	100	102	104	106	108	110	112	114	116	118	120	86.2
195	66	68	70	72	74	76	78	79	81	83	85	87	89	91	93	95	97	98	100	102	104	106	108	110	112	114	116	118	88.5
200	65	67	69	71	73	74	76	78	80	82	84	85	87	89	91	93	95	97	99	100	102	104	106	108	110	112	114	116	90.7
205	64	66	68	69	71	73	75	77	79	80	82	84	86	88	90	91	93	95	97	99	100	102	104	106	108	110	111	113	93.0
210	63	65	66	68	70	72	74	75	77	79	81	83	84	86	88	90	92	93	95	97	99	101	102	104	106	108	110	111	95.2
215	62	63	65	67	69	71	72	74	76	78	79	81	83	85	86	88	90	92	93	95	97	99	100	102	104	106	108	109	97.5
220	61	62	64	66	68	69	71	73	75	76	78	80	82	83	85	87	88	90	92	94	96	97	99	101	102	104	106	108	99.8
225	60	61	63	65	67	68	70	72	73	75	77	79	80	82	84	85	87	89	90	92	94	96	97	99	101	103	104	106	102.0
Vital Capacity in Cubic Inches	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	298.9	305.0	311.1	317.2	323.3	329.4	335.5	341.6	347.7	353.8	359.9	366.0	372.1	378.2	

Take the actual weight (without clothing) of the patient either in pounds or kilograms. (If the patient is obese or emaciated use the theoretical normal weight.) Locate in the vertical column at the extreme left or extreme right the figure which corresponds most closely to the weight. Now take the vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom the figures corresponding most closely to the vital capacity observed. Now use the table in precisely the same manner as table 10 is used.

TABLE 15

PERCENTAGE OF VITAL CAPACITY—WOMEN (CALCULATED FROM BODY WEIGHT)

Body Weight in Pounds	Vital Capacity in Cubic Centimeters																																											Body Weight in Kg.
	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	
80	26	31	35	39	44	48	53	57	61	66	70	74	79	83	88	92	97	101	105	110	114	118	123																					36.3
85	25	30	34	38	42	46	52	55	59	63	67	72	76	80	84	88	93	97	101	105	110	114	118	122																				38.5
90	24	28	32	36	41	45	49	53	57	61	65	69	73	77	81	85	89	93	97	101	105	109	114	118	122																			40.8
95	23	27	31	35	39	43	47	51	55	59	63	67	70	74	78	82	86	90	94	98	102	106	110	113	117	121																		43.1
100	23	26	30	34	38	42	45	49	53	57	60	64	68	72	75	79	83	87	91	94	98	102	106	109	113	117	121																	45.4
105	22	25	29	33	36	40	44	47	51	55	58	62	66	69	73	76	80	84	87	91	95	98	102	106	109	113	116	120																47.6
110	21	25	27	32	35	39	42	46	49	53	57	60	63	67	70	74	77	81	84	88	92	95	99	102	106	109	112	116	119															49.9
115	20	23	27	31	34	38	41	44	47	51	55	58	61	65	68	72	75	78	82	85	89	92	96	99	102	106	109	113	116	119														52.2
120	20	23	26	30	33	36	40	43	46	50	53	56	60	63	66	70	73	76	79	83	86	89	93	96	99	103	106	109	112	116	119													54.4
125	19	22	26	29	32	35	39	42	45	48	51	55	58	61	64	68	71	74	77	80	84	87	90	93	97	100	103	106	109	112	116	119												56.7
130	19	22	25	28	31	34	37	41	44	47	50	53	56	58	62	66	69	72	75	78	81	84	87	91	94	97	100	103	106	109	112	115	119											59.0
135		21	24	27	30	33	36	39	42	46	49	52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115	118	121									61.3
140		21	24	27	30	33	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	83	86	89	92	95	98	101	103	106	109	112	115	118	121								63.5
145		20	23	26	29	32	35	38	40	43	46	49	52	55	58	61	64	66	69	72	75	78	81	84	87	90	92	95	98	101	104	107	110	113	115	118	121							65.7
150		20	22	25	28	31	34	37	39	42	45	48	51	53	56	58	62	65	68	70	73	76	79	82	84	87	90	93	96	99	101	104	107	110	112	115	118	121						68.0
155		19	22	25	27	30	33	36	39	41	44	47	50	52	55	58	61	63	66	69	72	74	77	80	83	85	88	91	94	97	99	102	105	107	110	113	115	118	121					70.4
160		19	21	24	27	30	32	35	38	40	43	46	48	51	54	57	59	62	65	67	70	73	75	78	81	83	86	89	91	94	97	99	102	105	108	110	113	115	118	120				72.5
165			21	24	26	29	32	34	37	40	42	45	47	50	53	55	58	61	63	66	68	71	74	76	79	82	84	87	90	92	95	97	100	103	105	108	110	113	116	118	121			74.8
170			21	23	26	28	31	34	36	39	41	44	46	49	52	54	57	59	62	64	67	70	72	75	77	80	82	85	88	90	93	95	98	100	103	106	108	111	113	116	119	122		77.1
175			20	23	25	28	30	33	35	38	40	43	46	48	51	53	56	58	61	63	66	68	71	73	76	78	81	83	86	88	91	94	96	99	101	103	106	109	111	114	117	120		79.4
180			20	22	25	27	30	32	35	37	40	42	44	47	49	52	54	57	59	62	64	67	69	72	74	77	79	82	84	87	89	91	94	96	99	101	104	106	109	111	114	117	120	81.6
185			19	22	24	27	29	31	34	36	39	41	44	46	49	51	53	56	58	61	63	65	68	70	73	75	78	80	82	85	87	90	92	94	97	99	102	104	107	109	111	114	116	83.9
190				21	24	26	29	31	33	36	38	40	43	45	48	50	52	55	57	59	62	64	67	69	71	74	76	79	81	83	86	88	91	93	95	98	100	102	105	107	109	112	114	86.2
195				21	23	26	28	30	33	35	37	40	42	44	47	49	51	54	56	58	61	63	65	68	70	72	75	77	79	82	84	86	89	91	93	96	98	100	102	105	107	110	112	88.4
200				20	23	25	27	30	32	34	37	39	41	43	46	48	50	53	55	57	60	62	64	66	69	71	73	76	78	80	82	85	87	89	92	94	96	98	101	103	105	107	110	90.7
	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	153.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	
	Vital Capacity in Cubic Inches																																											

This table is used in the same manner as table 14. It may also be used for children

TABLE 16

PERCENTAGE OF VITAL CAPACITY-MEN (CALCULATED FROM SITTING HEIGHT)

Vital Capacity in Cubic Centimeters

Sitting height in inches	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200
30	21	24	28	31	34	38	42	45	49	52	55	59	62	66	69	73	76
30½	20	23	27	30	33	37	40	43	47	50	53	57	60	63	67	70	73
31	19	22	26	29	32	35	39	42	45	48	51	55	58	61	64	68	71
31½		22	25	28	31	36	39	42	45	47	49	53	56	59	62	66	69
32		21	24	27	30	34	37	40	43	45	47	51	54	57	60	63	67
32½		20	23	26	29	32	35	38	41	43	46	49	52	55	58	61	64
33		19	22	25	28	31	33	36	39	42	45	47	50	53	56	59	61
33½		19	22	24	27	30	32	35	38	40	43	46	49	51	54	57	59
34		.9	21	23.	26	29	31	34	37	39	42	44	47	50	52	55	57
34½			20	23	25	28	30	33	35	38	40	43	45	48	51	53	56
35			20	22	24	27	29	32	34	37	39	42	44	46	49	51	54
35½			19	21	24	26	28	31	33	36	38	40	43	45	47	50	52
36				21	23	25	28	30	32	34	37	39	4.	44	46	48	50
36½				20	22	24	27	29	31	33	36	38	40	42	44	47	49
37				19	22	24	26	28	30	32	35	37	39	41	43	45	47
37½				19	21	23	25	27	29	31	33	35	38	40	42	44	46
38					20	22	24	26	28	30	33	35	37	39	41	43	45
38½					20	22	24	26	28	30	32	34	35	37	39	41	43
39					19	21	23	25	27	29	31	33	35	36	38	40	42
39½					19	20	22	24	26	28	30	32	34	35	37	39	41
40						20	22	24	25	27	29	31	33	34	36	38	40
Vital Capacity in Cubic Inches	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2

Sitting height in inches	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000
30	80	83	87	90	93	97	100	104	107	110	114	118	121					
30½	77	80	83	87	90	93	97	100	103	107	1.0	113	116	120				
31	74	77	80	84	87	90	93	97	100	103	106	109	112	116	119			
31½	71	75	77	81	84	87	90	93	96	99	102	105	108	111	115	118	120	
32	69	72	74	78	81	84	87	90	93	96	99	102	105	107	111	114	117	119
32½	67	69	72	75	78	81	84	87	90	93	96	98	101	104	107	110	113	115
33	64	67	70	73	75	78	81	84	87	89	92	95	98	100	103	106	109	111
33½	62	65	67	70	73	76	78	81	84	86	89	92	94	97	100	102	105	108
34	60	63	65	68	70	73	76	78	81	83	86	89	91	94	96	99	102	104
34½	58	61	63	66	68	71	73	76	78	81	83	86	89	91	93	96	99	101
35	56	59	61	63	66	68	71	73	76	78	81	83	85	88	90	93	95	98
35½	55	57	59	62	64	66	69	71	73	76	78	81	83	85	88	90	92	95
36	53	55	57	60	62	64	67	69	71	73	76	78	80	83	85	87	89	92
36½	51	53	56	58	60	62	64	66	69	71	73	76	78	80	82	84	87	89
37	50	52	54	56	58	61	63	65	67	69	71	73	75	78	80	82	84	86
37½	48	50	52	54	56	59	61	63	65	67	69	71	73	75	77	79	82	84
38	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81
38½	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79
39	44	46	48	50	52	54	56	57	59	61	63	65	67	69	71	73	75	77
39½	43	45	46	48	50	52	54	56	58	59	61	63	65	67	69	71	73	74
40	42	43	45	47	49	51	53	54	56	58	60	62	63	65	67	69	71	72
Vital Capacity in Cubic Inches	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0

Sitting height in inches	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	6000	Sitting height in cm.
30																					76.2
30½																					77.5
31																					78.7
31½																					80.0
32																					81.3
32½	118	121																			82.6
33	114	117	120																		83.8
33½	110	113	116	119	121																85
34	107	.09	111	114	117	120															86.4
34½	104	.06	108	111	113	116	119	.21													87.6
35	100	.02	105	107	110	112	115	117	120												89
35½	97	100	102	104	106	109	111	114	116	118	121										90.2
36	94	97	99	101	103	105	108	110	112	114	117	119	121								91.5
36½	91	93	96	98	,00	102	104	106	109	111	113	115	118	120							92.7
37	88	91	93	95	97	99	101	104	106	108	110	112	114	1,6	118	121					94.0
37½	86	88	90	92	94	96	98	100	102	104	106	108	111	113	115	N7	119	121			95.2
38	83	85	87	89	91	93	95	97	99	101	103	105	107	109	111	113	115	117	119	121	96.5
38½	81	83	85	87	89	91	93	94	96	98	100	102	104	106	108	110	112	114	116	118	97.8
39	79	80	82	84	86	88	90	92	94	96	98	100	101	103	105	107	109	111	113	115	99.0
39½	76	78	80	82	84	86	87	89	91	93	95	97	98	100	102	104	106	108	110	111	100.3
40	74	76	78	80	81	83	85	87	89	91	92	94	96	98	100	101	103	105	107	109	101.6
Vital Capacity in Cubic Inches	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	298.9	305.0	311.1	317.2	323.3	329.4	335.5	341.6	347.7	353.8	359.9	366.0	

Take the sitting height of the patient, either in inches or centimeters. Locate in the vertical column, at the extreme left or extreme right of the table, the figure which corresponds most closely to the sitting height. Take the patient's vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom of the table the figure which corresponds most closely to the vital capacity observed. Now use the table in precisely the same manner as table 10 is used. (After Myers.)

TABLE 17

PERCENTAGE OF VITAL CAPACITY WOMEN (CALCULATED FROM SITTING HEIGHT)

Sitting height in inches	Vital Capacity in Cubic Centimeters																																										Sitting height in cm.
	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	
26	22	27	32	38	43	49	54	59	65	70	76	81	86	92	97	103	108	113	119																									66.0
26½	21	26	31	36	41	46	52	57	62	67	72	77	83	88	93	98	103	108	113	119																								67.3
27	20	25	30	35	39	44	49	54	59	64	69	74	79	84	89	94	99	104	108	114	119																								68.6
27½	19	24	28	33	38	43	47	52	57	62	66	71	76	81	85	90	95	100	104	109	114	118																								69.8
28		23	27	32	36	41	45	50	55	59	64	68	73	77	82	86	91	96	100	105	109	114	118																							71.1
28½		22	26	30	35	39	44	48	52	57	61	65	70	74	79	83	87	92	96	100	105	109	113	118																						72.3
29		21	25	29	33	38	42	46	50	54	59	63	67	71	75	80	84	88	92	96	100	105	109	113	117	121																			73.6
29½		20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	93	97	100	104	108	112	116	120																			75.0
30		19	23	27	31	35	39	43	47	50	54	58	62	66	70	74	78	82	85	89	93	97	101	105	108	112	116	120																		76.2
30½		19	22	26	30	34	37	41	45	49	52	56	60	63	67	71	75	78	82	86	90	93	97	101	105	108	112	116	119																	77.5
31			22	25	29	32	36	40	43	47	50	54	58	61	65	68	72	75	79	83	86	90	94	97	101	105	108	112	115	119																78.7
31½			21	24	28	31	35	38	42	45	49	52	55	59	62	66	69	73	76	80	83	87	90	94	97	100	104	107	111	114	118	121														80.0
32			20	23	27	30	33	37	40	44	47	50	54	57	60	64	67	70	74	77	80	84	87	90	94	97	100	104	107	110	114	117	120													81.3
32½			19	23	26	29	32	35	39	42	45	48	52	55	58	61	65	68	71	74	77	81	84	87	90	94	97	100	103	106	110	113	116	119												82.6
33			19	22	25	28	31	34	37	41	44	47	50	53	56	59	62	65	68	72	75	78	81	84	87	90	94	97	100	103	106	109	112	115	118	121										83.8
33½				21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	100	102	105	108	112	114	117	120									85.1
34				20	23	26	29	32	35	38	41	44	46	49	52	55	58	61	64	67	70	73	76	79	81	84	87	90	93	96	99	102	104	108	110	113	115	119								86.4
34½				20	22	25	28	31	34	37	39	42	45	48	51	54	56	59	62	65	68	70	73	76	79	82	84	87	90	93	96	98	101	104	106	109	112	115	118	121						87.6
35				19	22	24	27	30	33	35	38	41	43	46	49	52	54	57	60	63	65	68	71	73	76	79	82	84	87	90	92	95	98	100	103	106	109	111	114	117	120	122				89
35½					21	24	26	29	32	34	37	40	42	45	47	50	53	55	58	61	63	66	69	71	74	76	79	82	84	87	90	92	95	97	100	103	105	108	111	113	116	118	121				90.2
	24.4	30.5	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	
	Vital Capacity in Cubic Inches																																										

This table is used in the same manner as table 16. (After Myers)

TABLE 18

PERCENTAGE OF VITAL CAPACITY,—MEN (CALCULATED FROM CHEST CIRCUMFERENCE)

Chest Circumference (inches)	Vital Capacity in Cubic Centimeters																																																						Chest Circumference (cm.)
	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	6000	
28	21	24	28	31	34	38	41	45	48	52	55	59	62	66	69	73	76	80	83	87	90	93	97	100	104	107	111	114	117	121																										71.1
28.5	20	23	27	30	33	37	40	43	47	50	53	57	60	64	67	70	74	77	80	84	87	90	94	97	100	104	107	110	114	117	120																									72.3
29	19	23	26	29	32	35	39	42	45	48	52	55	58	61	65	68	71	74	77	81	84	87	90	94	97	100	103	106	110	113	116	119																								73.6
29.5	19	22	25	28	31	34	38	41	44	47	50	53	56	59	63	66	69	72	75	78	81	84	87	91	94	97	100	103	106	109	112	115	119																							75.0
30		21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	76	79	82	85	88	91	94	97	100	103	106	109	112	115	118	121																					76.2
30.5		20	23	26	29	32	35	38	41	44	47	50	53	56	59	61	64	67	70	73	76	79	82	85	88	91	94	97	99	102	105	108	111	114	117	120																				77.5
31		20	23	25	28	31	34	37	40	42	45	48	51	54	57	59	62	65	68	71	74	76	79	82	85	88	91	93	96	99	102	105	107	110	113	116	119	122																		78.7
31.5		19	22	25	27	30	33	36	38	41	44	47	49	52	55	58	60	63	66	69	71	74	77	79	82	85	88	90	93	96	99	101	104	107	109	112	115	118	121																	80.0
32		19	21	24	27	29	32	35	37	40	43	45	48	51	53	56	59	61	64	67	69	72	74	77	80	83	85	88	90	93	96	99	101	104	106	109	112	114	117	120																81.3
32.5			21	23	26	28	31	34	36	39	41	44	46	49	52	54	57	59	62	64	67	70	72	75	77	80	82	85	88	90	93	95	98	101	103	106	108	111	113	116	119	121														82.6
33			20	22	25	28	30	32	35	38	40	42	45	48	50	52	55	57	60	63	65	67	70	72	75	77	80	82	85	87	90	92	95	97	100	102	105	108	110	112	115	117	120													83.8
33.5			19	22	24	27	29	32	34	36	39	41	43	46	49	51	54	56	58	61	63	66	68	71	73	75	78	80	83	85	88	90	92	95	97	100	102	105	107	109	112	114	117	119	122											85.0
34				21	24	26	28	31	33	35	38	40	42	45	47	49	52	54	57	59	61	64	66	68	71	73	75	78	80	82	85	87	90	92	94	97	99	101	104	106	108	111	113	115	118	120										86.4
34.5				21	23	25	27	30	32	34	37	39	41	44	46	48	51	53	55	57	59	62	64	67	69	71	73	76	78	80	83	85	87	90	92	94	96	99	101	103	105	108	110	112	115	117	119	121								87.6
35				20	22	24	27	29	31	33	36	38	40	42	44	47	49	51	53	56	58	60	62	64	67	69	71	73	76	78	80	82	84	87	89	91	93	96	98	100	102	104	107	109	111	113	115	118	120							89.0
35.5				19	22	24	26	28	30	33	35	37	39	41	43	46	48	50	52	54	56	59	61	63	65	67	69	72	74	76	78	80	82	85	87	89	91	93	95	98	100	102	104	106	108	110	113	115	117	119	121					90.2
36				19	21	23	25	27	29	32	34	36	38	40	42	44	46	48	50	53	55	57	59	61	63	65	67	69	72	74	76	78	80	82	84	86	88	91	93	95	97	99	101	103	105	107	109	112	114	116	118	120				91.5
36.5					20	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	113	115	117	119	121		92.7
37					20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	94.0
37.5					19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	85	87	89	91	93	95	97	99	101	103	105	107	109	111	113	115	117	95.2
38					19	21	23	25	27	28	30	32	34	36	38	40	42	44	45	47	49	51	53	55	57	59	61	62	64	66	68	70	72	74	76	78	80	81	83	85	87	89	91	93	95	97	98	100	102	104	106	108	110	112	114	96.5
38.5						20	22	24	26	28	30	31	33	35	37	39	41	43	44	46	48	50	52	54	55	57	59	61	63	65	67	68	70	72	74	76	78	79	81	83	85	87	89	91	92	94	96	98	100	102	103	105	107	109	111	97.8
39						20	21	23	25	27	29	31	32	34	36	38	40	41	43	45	47	49	50	52	54	56	58	59	61	63	65	67	68	70	72	74	76	77	79	81	83	85	86	88	90	92	94	95	97	99	101	102	104	106	108	99.0
39.5						19	21	23	25	26	28	30	32	33	35	37	39	40	42	44	46	47	49	51	53	54	56	58	60	61	63	65	67	69	70	72	74	75	77	79	81	83	84	86	88	90	91	93	95	97	98	100	102	103	105	100.3
40						19	21	22	24	26	27	29	31	33	34	36	38	39	41	43	45	46	48	50	51	53	55	57	58	60	62	64	65	67	69	70	72	74	75	77	79	81	82	84	86	87	89	91	93	94	96	98	99	101	103	101.6
40.5							20	22	23	25	27	28	30	32	33	35	37	38	40	42	43	45	47	48	50	52	53	55	57	58	60	62	63	65	67	68	70	72	73	75	77	78	80	82	83	85	87	88	90	92	93	95	97	98	100	102.8
41							19	21	23	25	26	28	29	31	33	34	36	38	39	41	42	44	46	47	49	51	52	54	56	57	59	60	62	64	65	67	69	70	72	73	75	77	78	80	82	83	85	87	88	90	91	93	95	96	98	104.1
41.5							19	21	22	24	25	27	29	30	32	33	35	37	38	40	41	43	45	46	48	49	51	53	54	56	57	59	61	62	64	65	67	68	70	72	73	75	76	78	80	81	83	84	86	88	89	91	92	94	96	105.4
42							19	20	22	23	25	26	28	30	31	33	34	36	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61	62	64	65	67	68	70	72	73	75	76	78	79	81	82	84	86	87	89	90	92	93	106.6
	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	298.9	305.0	311.1	317.2	323.3	329.4	335.5	341.6	347.7	353.8	359.9	366.0	
	Vital Capacity in Cubic Inches																																																							

Locate in the vertical column at the extreme left or extreme right the figure which corresponds most closely with chest circumference of the patient. Take the patient's vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom of the table the figure which corresponds most closely to the vital capacity observed. Now use the table in precisely the same manner as table 10 is used.

TABLE 19

PERCENTAGE OF VITAL CAPACITY,- WOMEN (CALCULATED FROM CHEST CIRCUMFERENCE)

Chest Circumference (inches)	Vital Capacity in Cubic Centimeters																																													Chest Circumference (cm.)
	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	
24	19	25	30	35	39	44	49	54	59	64	69	74	79	84	89	94	99	104	108	113	118	123																								61
24.5	19	23	28	33	37	42	46	51	56	61	65	70	75	79	84	89	94	98	103	107	112	117	121																							62
25	18	22	27	31	36	40	45	49	53	58	62	67	71	76	80	85	89	93	98	102	107	111	115	120																						63
25.5		21	25	30	34	38	42	46	51	55	59	63	68	72	76	80	84	89	93	97	101	105	110	114	118																					64
26		20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	87	92	97	100	104	108	112	116	120																			65
26.5		19	23	27	31	34	38	42	46	50	54	58	61	65	69	73	77	80	84	88	92	96	100	103	107	111	115	119																		66
27		18	22	26	29	33	37	40	44	47	51	55	58	62	66	69	73	77	80	84	88	91	95	99	102	106	109	113	117	120																67
27.5			21	24	28	31	35	38	42	45	49	52	56	59	63	66	70	73	77	80	84	87	91	94	98	101	104	108	111	115																68
28			20	23	27	30	33	37	40	43	47	50	53	57	60	63	67	70	73	77	80	83	87	90	93	97	100	103	107	110	113	117														69
28.5			19	22	25	29	32	35	38	41	45	48	51	54	57	60	64	67	70	73	76	80	83	86	89	92	95	99	102	105	108	111	114	118												70
29			18	21	24	27	30	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	79	82	85	88	91	95	98	101	104	106	110	113	116	119										71
29.5				20	23	26	29	32	35	38	41	44	47	50	53	55	58	61	64	67	70	73	76	79	82	85	87	90	93	96	99	102	105	108	111	114	117	120								72
30				20	22	25	28	31	34	36	39	42	45	48	50	53	56	59	62	64	67	70	73	75	78	81	84	87	89	92	95	98	101	103	106	109	112	114	117	120						73
30.5				19	22	24	27	30	32	35	38	40	43	46	48	51	54	56	59	62	64	67	70	72	75	78	81	83	86	89	91	94	97	99	102	104	107	110	113	115	118	121				74
31				18	21	23	26	28	31	33	36	39	41	44	46	49	51	54	57	59	62	64	67	70	72	75	77	80	82	85	87	90	93	95	98	100	103	105	108	111	113	116	118	121		75
31.5					20	22	25	27	30	32	35	37	40	42	44	47	49	52	54	57	59	62	64	67	69	72	74	77	79	82	84	86	89	91	94	96	99	101	104	106	109	111	114	116	119	76
32					19	21	24	26	29	31	33	36	38	40	43	45	47	50	52	55	57	59	62	64	67	69	71	74	76	78	81	83	85	88	90	93	95	97	100	102	104	107	109	111	114	77
32.5					18	21	23	25	27	30	32	34	37	39	41	43	46	48	50	53	55	57	59	62	64	66	69	71	73	75	78	80	82	84	87	89	91	94	96	98	100	103	105	107	110	78
33						20	22	24	26	29	31	33	35	37	40	42	44	46	48	50	53	55	57	59	61	64	66	68	70	72	75	77	79	81	83	86	88	90	92	94	97	99	101	103	105	79
33.5						19	21	23	25	28	30	32	34	36	38	40	42	44	47	49	51	53	55	57	59	61	63	66	68	70	72	74	76	78	80	82	85	87	89	91	93	95	97	99	101	80
34							20	22	24	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	86	88	90	92	94	96	98	81
34.5							20	22	24	26	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	78	80	82	84	86	88	90	92	94	82
	24.4	30.5	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	
	Vital Capacity in Cubic Inches																																													

This table is used in the same manner as table 18

that even this ratio may be somewhat too high. Table 12 has proved quite satisfactory (figs. 31 and 32).

Body weight standard. In 1919 Dreyer presented a formula for obtaining the normal vital capacity. This formula is based on body weight, but body surface area is given due consideration. After extensive study of the subject of vital capacity, Dreyer came to the conclusion that vital capacity is more closely correlated with body surface than any other measurement. From a recent study of this subject Lemon and Moersch confirmed the findings of Dreyer and West and reached the conclusion "that vital capacity is more nearly a function of body surface than of any other body measurement. It has been shown that there is a very slight difference in the results obtained from Dreyer's formula and the method of West (figs. 31 and 32); therefore, it is permissible to use either. Tables 14 and 15 are easy to use since the only measurements required are body weight and vital capacity.

Hewlett and Jackson found that "Among college students the correlation of vital capacity with height and the correlation of vital capacity with weight are approximately equal. The correlation of vital capacity with a combination of weight and height is a little better than the correlation of either separately." For their combined method Hewlett and Jackson presented the following formula: Vital capacity = 27 × weight in kilograms—31.5 × standing height in centimeters—3000.

Sitting height standard. Hutchinson said: "I am inclined to believe the length of the trunk of the body has little to do in regulating the vital capacity." In 1853 Fabius was convinced that a definite correlation exists between the vital capacity of the lungs and the length of the trunk.

His trunk length measurement was taken from the tip of the coccyx to the occipital protuberance. Since Fabius' work, Arnold, Cornet, Dreyer and others have employed standards based on the trunk length. It has been shown that a tall person may have a short trunk and a small chest capacity whereas a short person may have a long trunk and a large chest capacity. Therefore, Dreyer believes that the sitting height standard is extremely valuable. Since Dreyer's publication, Rogers, Boynton, Shepard, Cripps, Greenwood and Newbold and others have pointed out that the sitting height standard shows more variation than other standards employed and is not materially better than the standing height standard (figs. 31 and 32). However, in view of the fact that one encounters occasional short persons with long trunks and tall persons with short trunks, and of the fact that further observations should be made on the correlation between sitting height and vital lung capacity, before any sweeping conclusions may be drawn, tables 16 and 17, made with the aid of Dreyer's formulae, are presented.

Chest Circumference standard. Hutchinson said: "I do not find there exists any direct relation between the circumference of the chest and the vital capacity." Only two years later, however, Simon published the results of his work on vital capacity in which he showed that a correlation exists between the circumference of the chest and the vital lung capacity. Later, Fabius, Arnold, Cornet, Demonet, Dreyer, Cripps, Greenwood and Newbold and others employed the chest circumference in vital capacity studies. The chest circumference standard has shown considerable more variation than some of the other standards; however, tables 18 and 19 were prepared by the aid of Dreyer's

TABLE 20

Vital capacity, in cubic centimeters, of normal boys, for each 5 cm. difference in standing height at each age, and average vital capacity for each 5 cm. of growth in height, combining all ages

After Stewart

AGE	STANDING HEIGHT																		
	98	103	108	113	118	123	128	133	138	143	148	153	158	163	168	173	178	183	188
years																			
5	837	767	978	975	925														
6		808	1,122	1,159	1,245	1,333													
7			1,079	1,215	1,303	1,396	1,620		2,200										
8				1,242	1,355	1,480	1,707	1,650	1,800										
9				1,400	1,450	1,537	1,672	1,794	1,992	2,075									
10					1,525	1,660	1,662	1,872	2,001	2,227	1,900								
11						1,463	1,808	1,827	2,065	2,150	2,184								
12						1,300	1,575	1,800	2,059	2,151	2,323	2,655	2,975	3,000					
13								1,908	2,132	2,244	2,378	2,546	2,768	3,281	3,400				
14									1,938	2,298	2,400	2,584	2,906	3,022	3,328	3,538	3,950		
15										2,445	2,565	2,727	2,971	3,200	3,673	3,893	3,862		
16										2,400	2,400	2,400	3,236	3,205	3,644	3,958	4,180		
17													2,833	2,850	3,813	3,973	4,262	4,050	4,300
18													2,750		3,925	4,125	4,200	4,400	
19														4,300	4,300	4,300			
Absolute increased vital capacity...	837	788	1,074	1,190	1,332	1,474	1,690	1,828	2,050	2,230	2,359	2,594	2,936	3,173	3,625	3,919	4,094	4,167	4,300

TABLE 21

Vital capacity, in cubic centimeters, of girls, for each 5 cm. difference in standing height at each age, and average vital capacity for each 5 cm. of growth in height, combining all ages

After Stewart

AGE	STANDING HEIGHT																	
	88	95	98	103	108	113	118	123	128	133	138	143	148	153	158	163	168	173
years																		
4	612	650	692	850														
5			850	850	914	1,050	1,100											
6				806	1,034	1,082	1,283	1,317										
7				950	1,094	1,131	1,239	1,356	1,440	1,800								
8				900	1,000	1,231	1,311	1,444	1,455	1,780								
9						1,150	1,294	1,430	1,509	1,687	1,820	1,850						
10						1,075	1,333	1,423	1,588	1,684	1,821	1,980	2,183	2,150				
11							1,325	1,342	1,632	1,703	1,820	1,943	2,143	2,050				
12								1,450	1,725	1,700	1,925	1,996	2,110	2,352	2,533	2,950		
13									1,650	1,650	1,957	2,020	2,257	2,381	2,515	2,865	3,040	
14											2,150	2,200	2,292	2,467	2,678	2,824	3,131	3,100
15												2,210	2,294	2,590	2,708	2,869	3,010	
16														2,733	2,786	2,733	2,850	
17														2,250		3,030	3,100	
Average vital capacity . .	612	650	755	851	1,022	1,118	1,238	1,412	1,555	1,698	1,870	2,005	2,211	2,449	2,661	2,855	3,017	3,100

TABLE 22

Vital capacity, in cubic centimeters, of normal boys for every 2 cm. difference in sitting height at each age, and average vital capacity for each 2 cm. growth in stem length, combining all ages

After Stewart

AGE	SITTING HEIGHT																					
	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95
years																						
5	950	800	910	1,025	1,008	1,150																
6		1,125	1,061	1,172	1,184	1,329	1,200															
7	1,000	1,150	1,150	1,176	1,300	1,323	1,389	1,460	2,200													
8			1,200	1,300	1,294	1,424	1,556	1,632	1,825													
9				1,400	1,517	1,496	1,602	1,764	1,796	1,995	2,500	2,575										
10					1,525	1,817	1,679	1,728	1,920	1,988	2,031	2,200	2,650									
11						1,500	1,767	1,783	1,979	2,088	2,110	2,177	2,500	2,500								
12							1,700	1,850	1,950	2,050	2,144	2,241	2,406	2,650	2,788	2,800						
13								1,800	2,125	2,069	2,267	2,310	2,423	2,604	2,814	3,012	3,334		4,000			
14										2,158	2,100	2,396	2,512	2,659	2,813	3,023	3,221	3,395	3,850	3,450		4,250
15											2,400	2,311	2,688	2,788	2,926	3,269	3,288	3,666	3,853	3,769		
16												2,388	2,450	2,675	3,617	3,186	3,373	3,606	3,907	4,125	4,300	4,300
17																2,550	2,900	3,850	4,000	4,167	4,062	4,300
Average.	975	1,036	1,071	1,190	1,302	1,425	1,557	1,719	1,923	2,054	2,159	2,300	2,497	2,671	2,881	3,104	3,292	3,607	3,897	3,913	4,142	4,275

TABLE 23

Vital capacity, in cubic centimeters, of normal girls, for every 2 cm. difference in sitting at each age and average vital capacity for each 2 cm. growth in stem length, combining all ages

After Stewart

AGE	SITTING HEIGHT																				
	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91
years																					
5	750	950	867	859	1,067																
6		1,150	983	1,068	1,102	1,100	1,250	1,266													
7			900	1,094	1,098	1,158	1,353	1,400	1,325	1,400											
8				1,000	1,192	1,253	1,415	1,474	1,483	1,687	1,750										
9					1,167	1,383	1,425	1,423	1,540	1,738	1,850	2,000									
10					900	1,317	1,404	1,505	1,643	1,749	1,879	2,012	2,175	2,300	2,750						
11						1,250	1,431	1,612	1,609	1,773	1,862	1,943	1,975	2,050	2,117						
12							1,450	1,450	1,869	1,838	1,867	1,921	2,102	2,258	2,283	2,556	2,700				
13								1,700	1,600	1,933	2,000	1,933	2,149	2,236	2,437	2,470	2,713	2,967	2,883		
14												2,250	2,230	2,314	2,465	2,595	2,716	2,923	2,958	3,225	
15											2,000	2,000	2,150	2,240	2,567	2,686	2,820	2,846	3,029	3,093	
16															2,762	2,512	2,550	2,888	3,012		
17																2,250	2,700	3,017			3,100
18																		3,100			
Average.....	750	1,050	940	998	1,107	1,205	1,386	1,469	1,636	1,759	1,881	1,952	2,113	2,256	2,458	2,537	2,740	2,847	2,967	3,141	3,100

formulae and are presented for the same reason that sitting height tables were presented.

Stewart, Wilson and Edwards and others have pointed out that most standards used for adults are not applicable for children; therefore, tables 14, 20, 21, 22 and 23 will be found helpful when dealing with the vital lung capacity of children.

SUMMARY

In using the normal standard tables those based on surface area, weight or standing height are recommended. If the vital capacity percentage is found to be normal by these tables, the use of the other standards may be omitted. If, however, the vital capacity percentage is found to be abnormally low by these tables, recourse may be had to the tables developed from sitting height and chest circumference standards. When working with emaciated patients the theoretical normal weights or better the patient's usual weights while in good health should be used. In both emaciated and obese cases the standing height standard may give better results than any other standard. When recording the vital capacity, the standards used should be stated.

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Sans Tache

Sans Tache

IN THE "elder days of art" each artist or craftsman enjoyed the privilege of independent creation. He carried through a process of manufacture from beginning to end. The scribe of the days before the printing press was such a craftsman. So was the printer in the days before the machine process. He stood or fell, as a craftsman, by the merit or demerit of his finished product.

Modern machine production has added much to the worker's productivity and to his material welfare; but it has deprived him of the old creative distinctiveness. His work is merged in the work of the team, and lost sight of as something representing him and his personality.

Many hands and minds contribute to the manufacture of a book, in this day of specialization. There are seven distinct major processes in the making of a book: The type must first be set; by the monotype method, there are two processes, the "keyboarding" of the MS and the casting of the type from the perforated paper rolls thus produced. Formulas and other intricate work must be hand-set; then the whole brought together ("composed") in its true order, made into pages and forms. The results must be checked by proof reading at each stage. Then comes the "make-ready" and press-run and finally the binding into volumes.

All of these processes, except that of binding into cloth or leather covers, are carried on under our roof.

The motto of The Williams & Wilkins Company is *Sans Tache.* Our ideal is to publish books *"without blemish"*—worthy books, worthily printed, with worthy typography—books to which we shall be proud to attach our imprint, made by craftsmen who are willing to accept open responsibility for their work, and who are entitled to credit for creditable performance.

The printing craftsman of today is quite as much a craftsman as his predecessor. There is quite as much discrimination between poor work and good. We are of the opinion that the individuality of the worker should not be wholly lost. The members of our staff who have contributed their skill of hand and brain to this volume are:

Composing Room: Andrew Rassa, Herbert Leitch, John Crabill, William Koch, Edgar Simmons, Austin Uhland, Ferdinand Schilling, Roland Stultz, William Sanders, James Armiger, George Behr, William Fite, Walter Phillips, Edward Rice, Henry Shea, Richard King.

Keyboard: Harry Susemihl, Katherine Kocent, Eleanor Luecke, Minnie Foard.

Proof Room: Sarah Katzin, Alice Reuter, Mary Reed, Ruth Treischman, Ethel Strasinger, Lucille Bull, Angeline Eifert, Audrey Tanner, Edna Clark, Lewis Forney, Dorothy Strasinger, Lillian Gilland, Arthur Baker, Geraldine Brown.

Caster: Kenneth Brown, Ernest Wann, Mahlon Robinson, Charles Aher, George Smith, Frank Malanosky, Martin Griffen, Henry Lee, Frederick Wall.

Cutter: John Murphy.

Folder: Laurence Krug.

Press: Fred Lucker, August Hildebrand.

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